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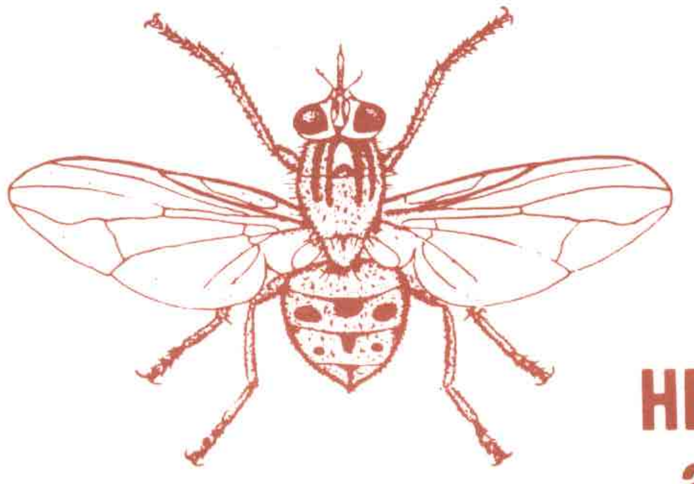
CDC MANUAL 5

Vector-Borne Disease Control



FLIES of PUBLIC HEALTH IMPORTANCE and THEIR CONTROL

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SELF-STUDY

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Centers for Disease Control
Public Health Practice Program Office
Atlanta, Georgia 30333

FLIES

OF PUBLIC HEALTH IMPORTANCE

AND THEIR CONTROL

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CONTENTS

INTRODUCTION

Flies and mosquitoes are insects of great public health importance. Mosquitoes, black flies, deer flies, horse flies, and many others bite man and animals viciously and seriously affect outdoor activities. The house fly and other species annoy man and animals and are pests both indoors and outdoors. More important, many flies breed in excrement and filth from which they carry disease-causing organisms to food, drinking water, or directly to the human body. Throughout the world, flies serve as mechanical or biological carriers of organisms causing some of the most common and important diseases such as typhoid fever, diarrhea, dysentery, cholera, trachoma, African sleeping sickness, and onchocerciasis. Larvae of some species of flies infest man or animals and cause serious sickness or even death, while other species attack and destroy crops. Today it is recognized that the abatement of fly populations is essential to man's well-being and to the control of many serious and widespread diseases.

Effective control of flies is dependent upon the accurate identification of species, knowledge of the life cycle and habits of problem species, and an understanding of the dynamics of fly populations. Present methods of fly control are only partially effective; ready answers cannot be given to every fly problem. However, recognized techniques, judiciously employed, can often reduce the numbers of flies and decrease the transmission of flyborne diseases. Improved environmental sanitation, the primary control measure, reduces the prevalence of many fly species and furnishes dividends in better living conditions for people.

This manual includes information about flies, their relationship to public health, their biology, and control. A list of references is included for the reader who wants additional information.

FLIES AND HUMAN WELFARE

ANNOYANCE

Domestic flies can affect individual efficiency. There are reports of people in fly-infested offices, near an open dump, an improperly operated sewage treatment plant, or a cattle feed lot, spending over 50 percent of their time swatting and driving away flies. Domestic flies can disrupt picnics and other recreational activities.

BITES

Not all flies bite, but those which do may cause serious trouble. Biting flies do not have venom in the usual sense. Instead the effects of their bites result from he human reaction to saliva poured into the bite wound to prevent clotting of the blood during the feeding process. Frequently biting flies, such as mosquitoes, black flies, punkies, horse flies, and deer flies seriously interfere with such activities as farming, hiking, camping, and outdoor sports, particularly in coastal areas or in the northern part of the United States. In susceptible individuals, the bites of these insects may produce severe lesions, hard knots beneath the skin, secondary infections, high fever, and general disability. The stable fly is common around human habitations and its bite can be quite severe. Black flies bite viciously, sometimes attacking in such numbers that they kill the victim. In the Balkans in 1923, over 16,000 domestic animals were killed by black fly attack (*24*). Eye gnats do not bite, but their rasping mouth parts damage the delicate membranes of the eye.

MECHANICAL TRANSMISSION OF ORGANISMS THAT CAUSE DISEASE

Many flies, particularly the house fly and other domestic flies, have filthy habits which make them efficient vectors of disease. Flies spread pathogens (disease-causing organisms) in five ways: (1) on their mouthparts, (2) through their vomitus, (3) on their body hairs, (4) on the sticky pads of their feet, and (5) through the intestinal tract by means of fly feces (*18*). West (*67*) and many other public health authorities consider that "The house fly is perhaps the most widely distributed as well as the most dangerous insect closely associated with man. Much sickness is due to fly-borne bowel infection." Under optimum conditions flies can be as effective in spreading enteric infections as are fingers, dirty eating utensils, and contaminated food. As a typical example, a house fly feeds on human feces in a privy used by a person suffering from diarrhea and later alights on food being prepared in a kitchen. The fly inoculates the food with pathogenic bacteria, such as the diarrhea bacteria (*Shigella*) or the typhoid bacillus (*Salmonella typhi*) which multiply rapidly in the food. When, hours later, the food is eaten, the people become infected and develop diarrhea (Figure 1). The classic demonstration of the relationship between flies and diarrheal disease was conducted in the Rio Grande Valley in Texas by CDC research workers in 1946 and 1947 as shown in Figure 2. In 1946 in one series of towns (Group A) which were not treated with insecticides, Watt and Lindsay (*66*) showed that there were high populations of flies and high *Shigella* infection rates in children under 10 years of age, many attacks of diarrheal disease, and a large number of deaths in children under two years of age. In a similar series of towns (Group B) with good control of flies, fly populations were low and there were low *Shigella* infection rates, few attacks of diarrheal disease, and few deaths due to enteric infections in children. In September 1947 when the control procedures were reversed in the two groups of towns, there were corresponding reversals in fly populations, *Shigella* infection rates, and number of cases of diarrheal disease (*32, 66*).

Domestic flies (particularly the house fly) mechanically transmit organisms causing bacillary dysentery, infantile diarrhea, typhoid fever, paratyphoid fever, cholera, amoebic dysentery, giardiasis, and pinworm, roundworm, and tapeworm infections (*18, 24*).

Flies with rasping mouthparts, such as eye gnats, are reported to carry the organisms that cause trachoma, epidemic pinkeye or conjunctivitis, and yaws. There is also evidence that the organisms which cause tularemia and anthrax are transmitted mechanically on the mouthparts of deer flies and horse flies from an infected animal to a healthy one (*24*).

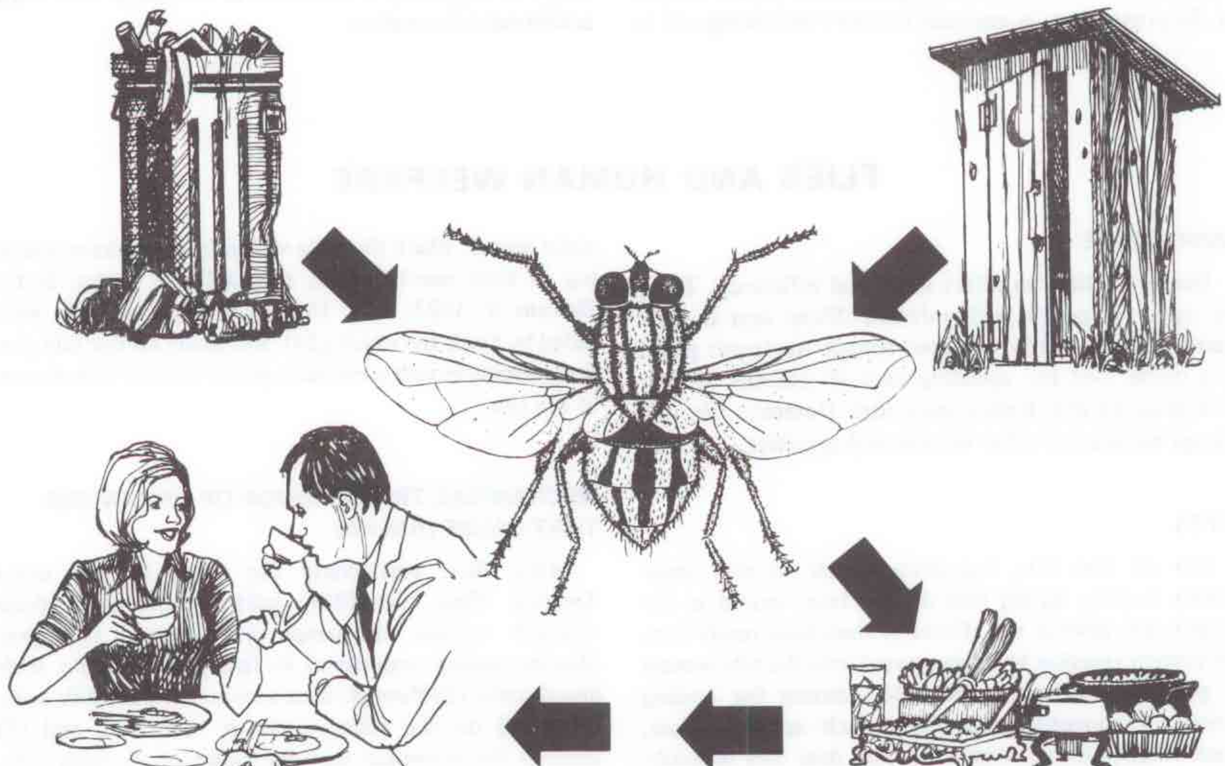


Figure 1. Mechanical Transmission of Disease-Causing Organisms by Flies.

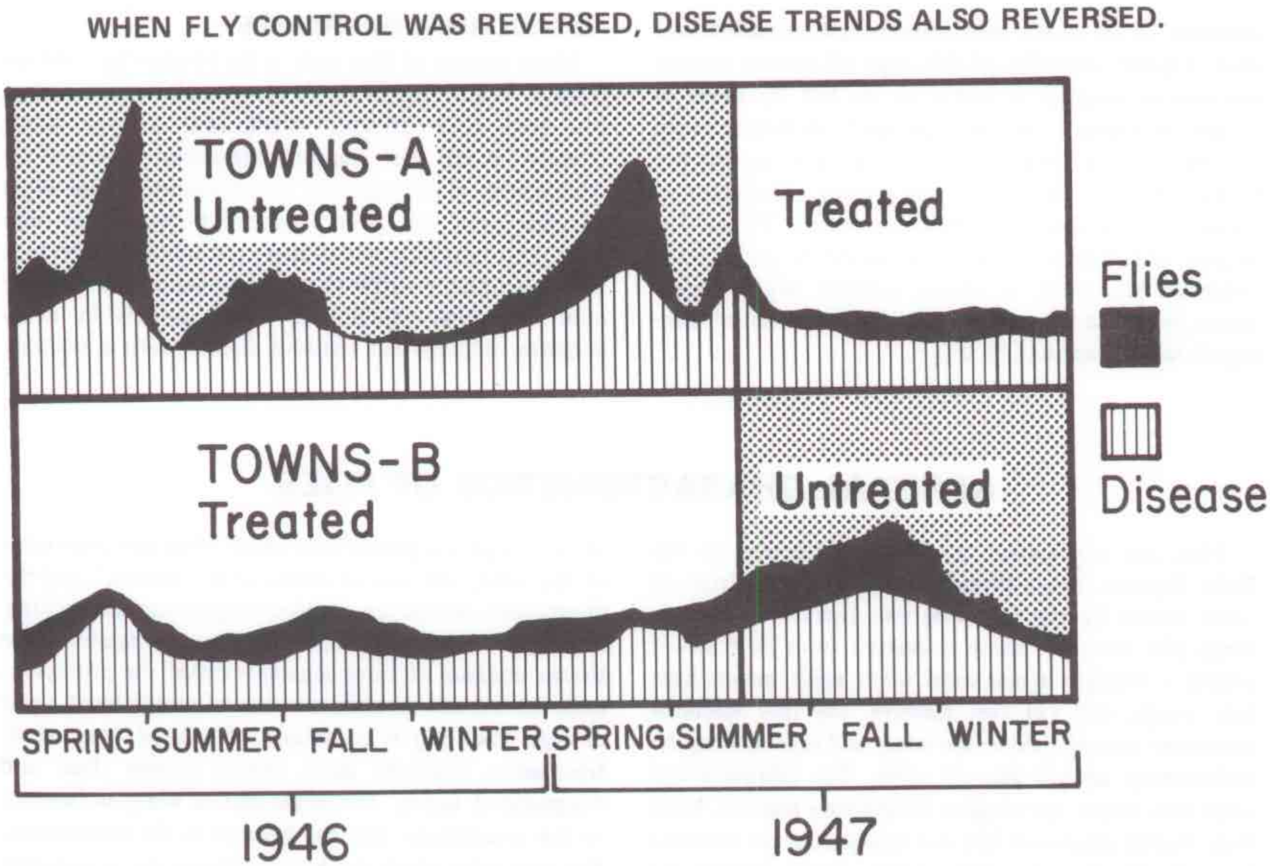


Figure 2. Relationship between Fly Populations and Enteric Disease. Adapted from Watt and Lindsay (*66*).

BIOLOGICAL TRANSMISSION OF ORGANISMS THAT CAUSE DISEASE

Many species of bloodsucking flies serve both as vectors and as intermediate hosts of pathogens, particularly of protozoa and heminths causing human diseases. This phenomenon is known as the biological transmission of disease-causing organisms. The mosquito-borne diseases provide some of the best examples of the biological transmission of the pathogen, or organism causing disease. There are three types of biological transmission (*24*):

1. **Propagative**. The parasites multiply within the vector but undergo no change in form, as with yellow fever, dengue, or encephalitis viruses in a variety of mosquitoes.

2. **Cyclo-developmental**. The parasites undergo changes in form within the vector but do not multiply in number, as with the filarial worms of human and canine filariasis in many mosquitoes.

3. **Cyclo-propagative**. The parasites undergo change in form and also multiply in numbers within the vector, as with the malarial parasite (*Plasmodium*) in *Anopheles* mosquitoes.

Other typical examples include the tsetse flies of Africa which transmit the trypanosomes causing African sleeping sickness of man and nagana of animals, the black flies which transmit the worms causing onchocerciasis (blinding filariasis) in Africa and Latin America, and the sandflies which transmit protozoa causing many forms of leishmaniases in Europe, Asia, Africa, and Central and South America. Other diseases having this type of epidemiology include loasis (African eye worm disease), bartonellosis (Oroya fever) of South America, and sandfly fever of the Mediterranean region.

MYIASIS

Many species of flies lay their eggs or larvae on the flesh of mammals, including man. The larvae then invade the flesh of the host animal, producing a condition known as myiasis. Cattle and sheep are commonly afflicted, as are many wild animals such as rabbits and deer. Typical examples of this type of myiasis are the screwworm maggots in cattle, or the bot fly larvae in horses. In addition, people may eat food infested with fly larvae. If the larvae survive the gastric juices and live in the alimentary canal, *intestinal myiasis,* manifested by queasiness and diarrhea frequently results. Typical examples of intestinal myiasis are caused by eating such foods as fish, meat, or cheese infested with flesh fly larvae or cheese skippers, or by drinking water containing rat-tailed maggots *(23, 57).*

AGRICULTURAL IMPORTANCE

Many species of flies such as the Hessian fly, cabbage maggot, onion maggot, apple maggot, clover seed midge, and seed corn maggot, attack and damage plants directly. Some flies transmit organisms causing plant disease such as bacterial soft rot of vegetables; fire blight of apple, pear, and quince; ergot of rye and wheat; olive knot; and bacterial rot of apple. In addition flies suck blood and annoy cattle to such an extent as to decrease milk and meat production, cause myiasis in many domestic animals, and transmit diseases such as anthrax.

GENERAL CHARACTERISTICS OF FLIES

Flies and mosquitoes are insects belonging to the Order Diptera. Adult Diptera are distinguished from all other insects by the following two characters: (1) **two wings** (the scientific name is derived from **Di** = two + **pteron** = wing), whereas most other adult insects have four wings; and (2) **two halteres**, the tiny knoblike structures located behind the wings and representing the rudimentary second pair of wings. The relatively few adult flies which are wingless always have halteres. More than 16,000 species of flies and mosquitoes are recorded from North America (*60*), while about 90,000 are recorded from the entire world. Many new species are described every year. There are many good, general accounts of flies *(11. 12, 24, 42, 70).*

ANATOMY

Adult flies have three distinct body regions: head, thorax, and abdomen (Figure 3). The head bears a pair of very large compound eyes which often comprise most of the head, one pair of antennae or "feelers," and the mouthparts, which are adapted for piercing and sucking, rasping, or sponging depending on the species. The thorax consists of three segments called the prothorax, mesothorax, and metathorax each of which bears a pair of legs. Each leg is composed of a basal coxa, short trochanter, relatively stout femur, slender tibia, and 5-segmented tarsus. The single pair of wings is fastened to the mesothorax and the halteres to the metathorax. The long veins which reach the wing margin, in domestic flies, are labeled Sc (for subcosta), then 1, 2, 3, 4, 5, 6. The shape of the vein 4 (straight, curved, or angled) is used in identification. The abdomen is composed of from four to nine segments and the genital organs.

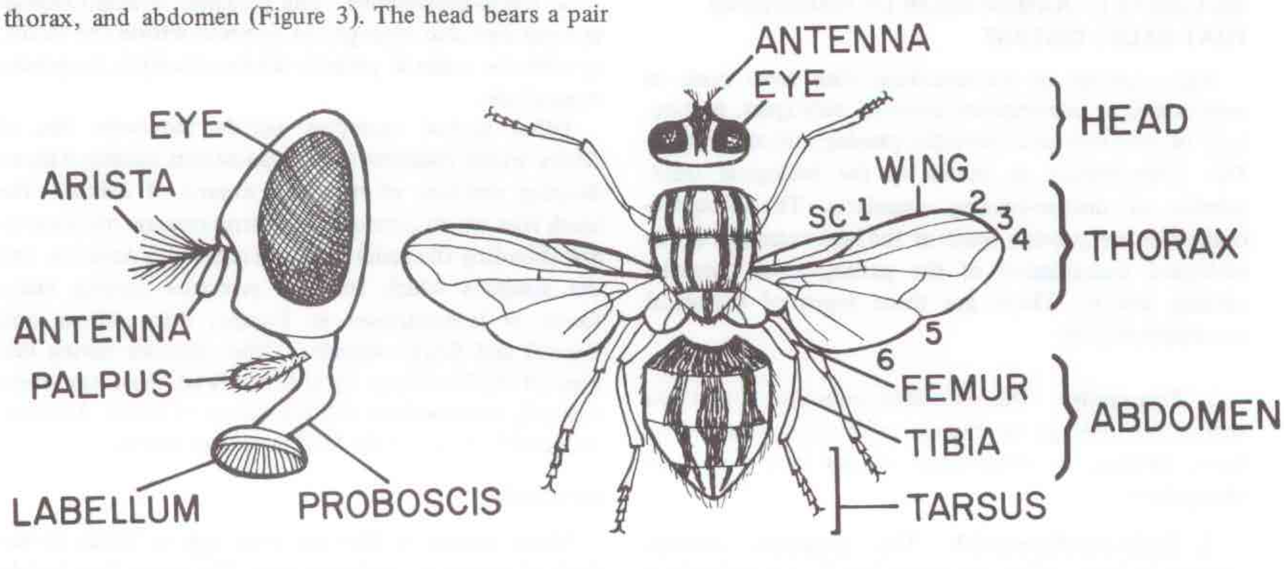


Figure 3. Anatomy of the House Fly

LIFE CYCLE

Flies have four stages in their life cycle: **egg**, **larva**, **pupa**, and **adult** and develop by a process known as **complete metamorphosis** (Figure 4). A few species, such as some flesh flies and tsetse flies, retain the eggs within the body of the female until hatching and give birth to larvae. In general, the larvae feed differently and occupy a different habitat from that of the adult. Larvae of mosquitoes are often called "wigglers" or "wrigglers" while larvae of most flies are commonly called "maggots." The pupae of many flies are enclosed in a tough skin known as a **puparium** and do not move very much. The time required for development from egg to the adult varies greatly, from a few days to more than a year, depending on the species of fly, and the environmental conditions, particularly the temperature and humidity.

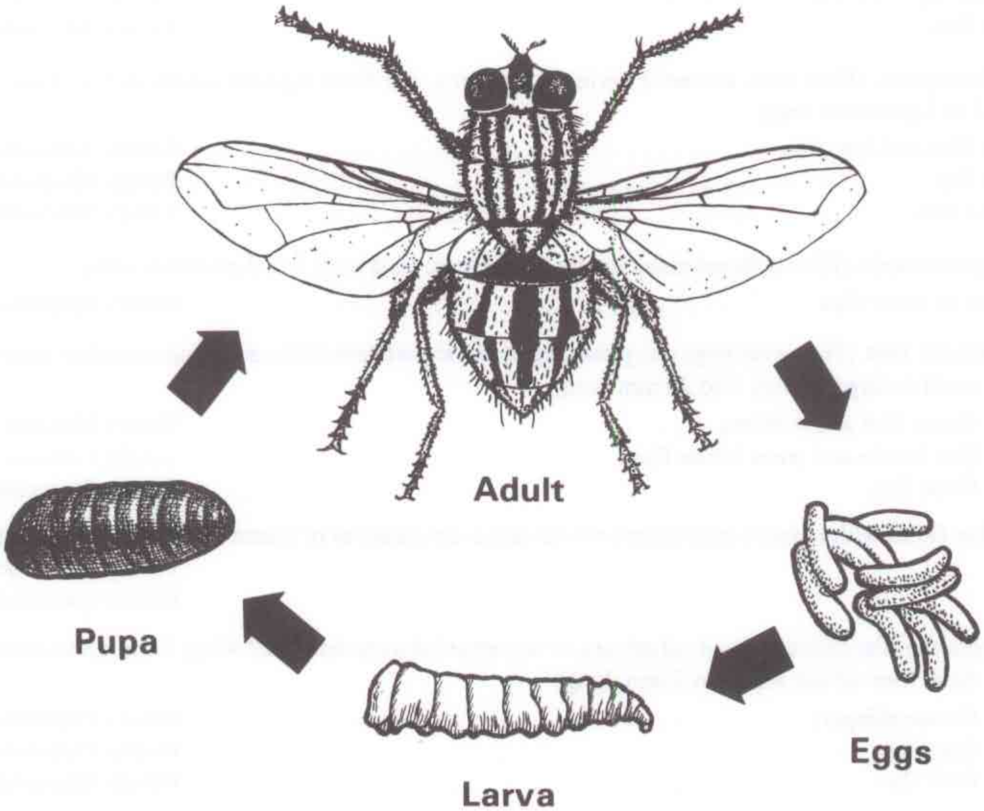


Figure 4. Life Cycle of the House Fly

IDENTIFICATION AND BIOLOGY OF FLIES

The order Diptera is a large one. The correct identification of many species is often difficult and requires special literature. However, the public health worker can learn to recognize the common domestic species, the families of flies of greatest public health importance, and the most common species of fly larvae by studying the pictorial keys in the appendix.

Students of the Order Diptera have divided the flies into three suborders and many families which can be identified with the naked eye after considerable study of the "Pictorial Key to Principal Families of Diptera of Public Health Importance," Appendix, p. 42. An outline of the classification of flies followed in this manual is presented in Table 1.

Many public health workers think of these insects either as **biting flies** (mosquitoes, horse flies, deer flies, stable flies, black flies, punkies, sand flies, and biting midges) or **nonbiting flies**, the so-called **domestic** or **synanthropic flies** (house flies, little or lesser house flies, blue bottle flies, green and bronze bottle flies, cluster flies, black blow flies, screwworm flies, and filter or moth flies).

TABLE 1. CLASSIFICATION OUTLINE OF THE FAMILIES IN THE ORDER DIPTERA

Suborder Nematocera (Flies with antenna having 10 or more distinct segments)	
Crane flies	Family Tipulidae
Mosquitoes	Family Culicidae
Midges	Family Chironomidae
	Family Chaoboridae
Filter flies, moth flies, sand flies	Family Psychodidae
Biting midges, punkies, no-see-ums	Family Ceratopogonidae
Black flies	Family Simuliidae
Suborder Brachycera (Flies with antennae having 3 segments, the third segment subdivided in many species; wing with 4 or 5 posterior cells)	
Horse flies and deer flies	Family Tabanidae
Snipe flies	Family Rhagionidae
Soldier flies	Family Stratiomyiidae
Suborder Cyclorrhapha (Flies with antennae having 3 segments; wing with 1 to 3 posterior cells)	
Flower or hover flies	Family Syrphidae
Calypterate flies (Flies with large calypteres, or squamae, between body and wing; complete mesonotal suture; small to large species, 3 to 20 mm. long)	
House flies and relatives	Family Muscidae
Blue bottle and green bottle flies	Family Calliphoridae
Flesh flies	Family Sarcophagidae
Bot flies (Flies with reduced mouthparts whose larvae are parasites of mammals)	Family Cuterebridae
	Family Oestridae
	Family Gasterophilidae
Acalypterate flies (Flies without calypteres, or squamae between body and wing; incomplete mesonotal suture; small flies usually less than 5 mm. long)	
Cheese skippers	Family Piophilidae
Eye gnats	Family Chloropidae
Fruit flies	Family Drosophilidae
Pupipara (Ectoparasitic flies on birds and mammals with hard leathery bodies, short strong legs, widely separated; winged or wingless)	
Sheep ked and louse flies	Family Hippoboscidae

DOMESTIC FLIES
(Families Muscidae, Calliphoridae, Sarcophagidae)

The domestic flies include the house flies and other typical calypterate flies with 3-segmented antennae, a conspicuous calyptere or squama between the body and wing, averaging 3 to 20 mm. long. With practice and reference to the "Pictorial Key to Common Domestic Flies" on page 43, public health workers can learn to recognize with the naked eye three groups based on the color of the thorax and abdomen: (1) those with a dull thorax and a dull abdomen include the house fly, little or lesser house fly, stable fly, and flesh fly; (2) those with a dull thorax and shiny, metallic, blue, green, or purple abdomen include the blue bottle flies; and (3) those with a shiny metallic green, blue, or purple thorax and abdomen include the green and bronze bottle flies, black blow fly, and screwworm fly.

HOUSE FLY AND RELATED FORMS
(Family Muscidae)

HOUSE FLY *(Musca domestica)*

The house fly is a small species, 6 to 9 mm. long, with dull thorax and abdomen, the thorax with four longitudinal dark stripes, the sides of the abdomen usually pale basally, and the fourth wing vein sharply angled, ending before the wing tip. The arista of the antenna has many fine hairs like a feather (Figure 5).

The house fly and its relatives are often termed "domestic" or "synanthropic" species because of their close association with man. The adults feed on human foods, and the larvae are often most abundant in human wastes such as excrement, garbage, and open dumps. There are many good illustrations, keys to important subspecies and relatives, and discussions of biology and control (*18, 23, 24, 67*).

The house fly occurs throughout the United States and is usually the most abundant species found in homes and restaurants. Studies by CDC research workers in the late 1940's and early 1950's (*54*) indicate that house flies make up over two-thirds of the total domestic fly populations in the hot, dry southwestern part of the United States and become relatively less predominant in the cooler and damper northern and eastern parts of the country. The relative abundance of house flies and blow flies is shown in Table 2 based on data from Schoof and Savage (*54*).

Because of the house fly's close association with man and his food, its habit of breeding in human excrement and other filth, its abundance, and its ability to transmit germs, it is considered to be a greater threat to human welfare than any of the other species (*18, 67*).

LIFE CYCLE

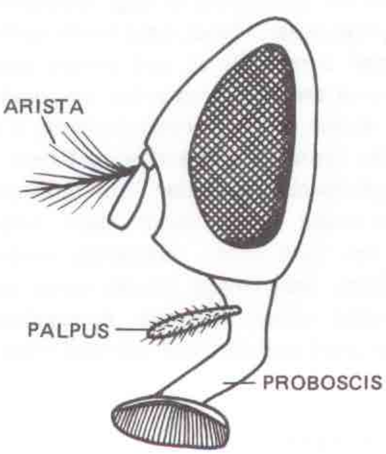
The developmental stages of the house fly require 8 to 20 days under average summer conditions (Figure 4). The female begins egg laying within 4 to 20 days after emergence as an adult. The small, white, oval eggs about one millimeter long are deposited in batches of 75 to 150. Five or six batches are laid during the lifetime of the average female, for a total of about 500 eggs per female. Eggs are usually placed in cracks and crevices in the breeding material away from direct light. Hatching occurs in 12 to 24 hours during the summer months. The active young larva burrows at once into the breeding media using its two mouth hooks for tearing and loosening food particles and for working its way along. The three larval stages last from 3 to 24 or more days. The usual time during warm weather is 4 to 7 days. Larvae regulate their temperature by moving to various levels in the breeding material. Studies indicate that feeding larvae choose temperatures from 86° to 95° F, those ready to pupate prefer lower temperatures. The distribution of larvae in the breeding media under natural conditions is believed to depend chiefly on temperature and moisture and, to a lesser extent, upon odors. When growth is completed, larvae migrate to drier portions of the media or leave it entirely, to burrow into soil or under debris to pupate.

TABLE 2. PERCENT OF HOUSE FLIES AND BLOW FLIES IN BAITED TRAPS – 1949-1950
Adapted from Schoof and Savage (*54*)

Species	Mesa-Tempe Arizona	Lawrence Kansas	Cohoes N.Y.
House Flies	66%	34%	3%
Blow Flies	32%	64%	95%

The mature larva (Figure 6) is about 12 mm long and creamy white in color. It is conical and has two dark mouth hooks at the anterior end and two oval spiracular plates at the broad posterior end. It is easily distinguished from other fly larvae by the three sinuous slits in each spiracular plate.

When ready to pupate, the larva contracts until the skin forms a capsulelike case about 6 mm in length. This



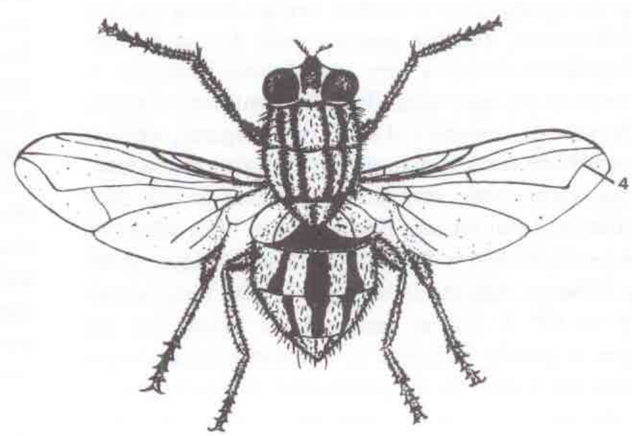


Figure 5. House Fly *(Musca domestica)*

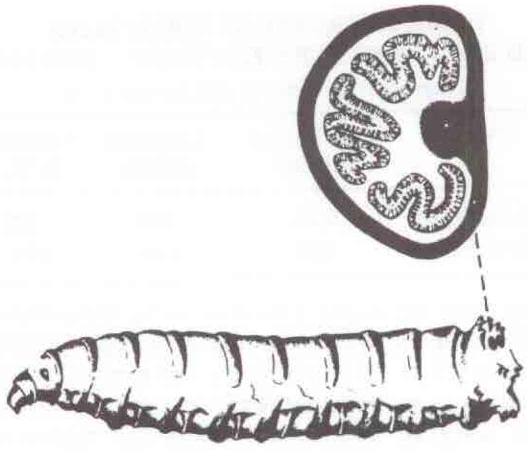


Figure 6. Larva of the house fly.

case (the puparium) encloses the true pupa which is immobile and takes no food. The pupal stage ordinarily lasts 4 to 5 days, but may be as short as 3 days at temperatures around 95° F or as long as several weeks at low temperatures. When the pupal period is complete, the fly breaks open the end of the puparium by the expansion of a bladderlike organ, the ptilinum, located on the front of the head. The fly then works its way out of the puparium and up to the surface of the soil. Here the wings unfold and the body expands, dries, and hardens. This requires about one hour under summer conditions. Adulthood is reached in about 15 hours. Mating may then take place.

Two or more generations per month may be produced during warm weather. Because of the rapid rate of development and the large number of eggs produced per female, populations build up rapidly. In the eastern half of the United States, populations build up gradually during the spring and summer and reach the maximum in late summer or early fall. However, in some south central and southwestern areas, densities may be greater during the spring, show a marked decline during the hot, dry midsummer, and the greatest peak during the late fall. Population densities vary considerably from year to year, even in the same area. Breeding continues throughout the year in tropical and subtropical regions, while in more northern areas it is interrupted during the winter. Eggs and larvae have very little resistance to cold, and adult flies will not emerge if pupae have been subjected to temperatures below 52° F, for 20 to 25 days, or 48° F for 24 hours. Adults can be kept alive for long periods at 50° to 60° F but at temperatures below this the life span is greatly reduced. In temperate zones, house flies pass the winter by a combination of adult hibernation and semicontinuous breeding in protected situations. In addition, house flies extend their range northward during the summer months into areas where they cannot survive the severe winters.

BREEDING MEDIA

Almost any type of warm, moist organic material may furnish suitable nourishment for house fly larvae. Animal manure is an excellent breeding medium, accounting for as many as 95% of the house flies in some rural areas. Fresh horse manure may produce as many as 1,200 larvae per pound. Manure of other animals (cows, pigs, rabbits, fowl, etc.) is also very suitable. Accumulations of fowl excrement are commonly infested with larvae, but scattered droppings in dry pens are seldom infested. Human excrement, often loaded with organisms pathogenic to man, is a dangerous source of fly breeding. Breeding occurs in privies, in exposed feces, and in incompletely digested sludge from sewage treatment plants. Garbage and pet manure are almost always the important source of house flies in urban communities. Fly breeding may be a problem if garbage is dumped indiscriminately on the premises or if it is stored in inadequate containers. Open garbage dumps, commonly present in and around cities, produce large numbers of flies (*32*).

ADULT FOOD

The adult house fly is very active, moving about busily from one attractant to another throughout most of the daylight hours. It is strongly attracted to feces and other types of decaying organic material, as well as to milk and foods intended for human consumption. Under natural conditions, house flies seek a wide variety of food substances and thereby obtain a balanced diet. Because of the nature of the house flies' mouthparts, their food must be in the liquid state or must be readily soluble in their salivary and crop secretions. The liquid food is sucked up through the spongy labellum at the tip of the proboscis (Figure 7). Water is essential and house flies will not ordinarily live more than 48 hours without it. Sugar or starch is necessary for long life, and protein is required for production of eggs. Common sources of food are milk, sugar, blood, meat broth, and many other foods found commonly in and around human habitations. Two or three feedings a day are necessary. As the house fly moves about over various items, it periodically regurgitates liquid from the crop and tests the surface with its proboscis, producing light strawcolored spots known as vomit spots. Darker spots which may be observed are fecal spots, commonly found on glass, walls, ceilings, light strings, electric wires, and on other surfaces upon which flies rest. Accumulations of fly specks are good indicators of habitual resting places of flies.

RESTING PLACES

Flies rest much of the time, showing a strong preference for edges. They rest indoors on light strings

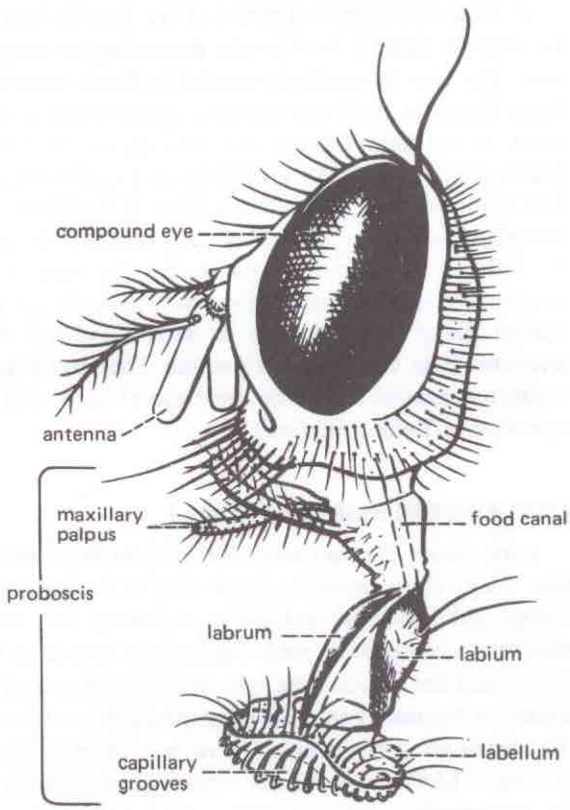


Figure 7. Mouthparts of house fly

and electric wires, walls, ceilings, and other places. They rest outdoors chiefly on fences, electric wires, edges of buildings, weeds and vegetation, particularly branches. Flies are essentially inactive at night. Their nighttime resting places are usually protected from the wind.

FLIGHT

House fly populations can disperse rapidly into new areas by flight. Although house flies cruise at only about 4 miles per hour and wander somewhat aimlessly, they travel as far as 6 miles (as the crow flies) within 24 hours, and as far as 20 miles, eventually. Flight range tests using flies tagged with radioactive materials have been performed in a number of different parts of the United States. After releasing the radioactive flies, the scientists set out baited traps in concentric circles around the release point. Most of these tagged flies recovered were trapped within one mile, but a few were taken as far as 20 miles from the point of release (*18, 53*).

LONGEVITY

Life span of the adult depends chiefly upon the availability of food and water, and upon temperature. Observations during midsummer in Texas indicate that when well fed, flies live 2 to 4 weeks. At Ithaca, New York, adult flies survived 70 days under experimental conditions. In hibernation, flies may live over winter, often from October to April (*24*).

TEMPERATURE

Flies are inactive at temperatures below 45° F and are killed by temperatures slightly below 32° F. Flight begins when air temperature is about 53° F, and complete activity occurs when it reaches about 70° F. Maximum activity is reached at 90° F, with a rapid decline at higher temperatures until 112° F, which produces paralysis and death (*18, 67*).

HUMIDITY

The effects of humidity are closely related to those of temperature, and it is difficult to assess one without consideration of the other. Lethal effects of both high and low temperatures are more marked when humidity is high. Above 60° F, flies live longest at a relative humidity of 42 to 55 percent. Below 68° F, they are active and long lived. Flies reach a physiological optimum at high temperatures and low humidities. This characteristic correlates with their great abundance in desert areas.

LIGHT

Flies are phototropic, that is, they generally move toward light. The success of the ordinary fly trap (page 22) depends upon this trait. The bait attracts flies to the lower part of the trap, and they are captured when they leave the bait and move around toward the light. Flies are inactive at night, but will resume activity under artificial illumination. The effects of light on fly activity are closely correlated with those of temperature and humidity.

WIND

Flies are sensitive to strong air currents and are not likely to venture out on extremely windy days. However, some are caught and carried great distances by high winds (such as hurricanes). House flies, probably windborne, have been collected over the ocean more than 100 miles from shore. At lower velocities, flies may travel with the wind or against it. They move upwind toward an attractive odor, against moderately strong winds, but move downwind on light breezes not bearing attractive odors.

NATURAL ENEMIES

Organisms which share its environment are of great importance to the house fly. Most of these organisms do no harm, but some act as parasites or predators. Natural enemies of flies include fungi, bacteria, protozoa, round worms, other arthropods, amphibians, reptiles, birds, and certain mammals, particularly man. Fungus infections may assume epizootic proportions, especially at the peak of the fly season, and may become one of the primary factors limiting fly populations (*18, 67*).

For years, many public health workers believed that privies were an important source of house fly production and enteric disease organisms. When the synthetic organic insecticides became available in the late 1940's and early 1950's, chlordane, BHC, and dieldrin were applied to the privy pits. For a time the insecticides seemed to give control; then, house fly production increased enormously in treated privies. Research by CDC workers indicated that untreated privies were characterized by heavy infestations of the soldier fly larvae, *Hermetia illucens,* and by semiliquid excreta. In contrast, the application of insecticides killed off the soldier fly larvae in the privy pits and reduced the water content of the excreta so that the material changed from a "soupy" consistency to a semisolid state favorable to house fly breeding (*28*).

FACE FLY *(Musca autumnalis)*

Face flies frequently are important household pests in cool weather. The adults enter buildings through openings and hibernate in masses in cool places such as attics, frequently with cluster flies and blue bottle flies. On warm winter days, or when these buildings are heated, they become active. Face and cluster flies have caused annoyance in hospital operating rooms which they entered by openings around ducts or electrical outlets, in large buildings where they found their way into air ducts, in homes where they buzzed around rooms or windows, or in churches warmed up on weekends for Sunday services. Sabrosky (*49*), James and Harwood (*24*) and others have shown good characters for separating the various stages of the house and face flies as summarized below:

A total developmental period of the face fly from egg to adult is about 2 to 4 weeks, depending on temperature. The face fly was first recorded in North America in Nova Scotia in 1952 and has since spread from coast to coast in southern Canada and throughout the United States south to Georgia, Oklahoma and California (*24*). The common name refers to the habit of these insects in congregating on the faces of cattle, often as many as 75 to 100 per animal, under and around the eyes, in and around the nostrils, and at the lips. Although face flies cannot pierce the skin, they do suck blood and other exudates from the surface of the skin. They transmit the organisms causing infectious pink eye of cattle and the eye worm (*Thelazia rhodesii*).

LITTLE HOUSE FLIES *(Fannia spp.)*

Little house flies are small flies seldom more than 7 mm long. They resemble house flies in having a dull thorax and abdomen, but differ in having only three relatively inconspicuous dark longitudinal stripes on the thorax and the fourth wing vein straight (Figure 8). The adults are frequently seen hovering in midair outdoors or less commonly in the middle of a room, a chicken house, or a barn. Little house flies lay their eggs particularly in the excrement of humans, horses, cows, and poultry, or sometimes in piles of decaying grasses piled up on lawns. The eggs hatch in about a day and the flattened, spiny larvae complete their development in a week or two depending on temperature. *Fannia* are of less importance as household pests or disease vectors than the house fly. However, there are numerous records of larvae of this genus causing myiasis in man (*23, 24*)

STABLE FLY *(Stomoxys calcitrans)*

The stable fly is distinguished from all other common domestic flies by its piercing proboscis which protrudes

TABLE 3. DIFFERENCES BETWEEN THE HOUSE FLY AND FACE FLY

Stage	House Fly	Face Fly
Female	Propleural depression haired Abdomen with pale spots laterally	Propleural depression bare Abdomen largely dark
Male	Eyes separated	Eyes nearly touching
Egg	Simple, laid on many types of warm, moist, organic material	With a respiratory filament, laid only in fresh cow droppings usually not over 15 minutes old.
Larva	Creamy white	Yellowish
Puparium	Reddish brown	Dirty white

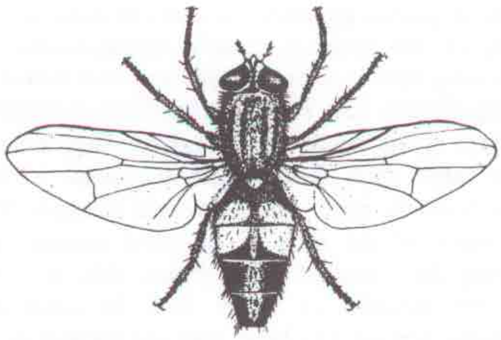


Figure 8. Little House Fly *(Fannia canicularis)*

bayonetlike in front of the head (Figure 9). This species is 5 to 6 mm long, has a dull thorax with four dark longitudinal stripes and a pale spot behind the head, and a dull colored abdomen with dark spots. The fourth wing vein is gently curved and ends near the wing tip. The arista of the antenna has fine hairs only on the upper side. Both male and female are vicious biters and attack man and a great variety of animals. The female lays her eggs in plant waste more often than in manure, in old straw stacks, piles of fermenting weeds, grass, peanut hay, or stable manure well-mixed with straw or hay. The stable fly is a major pest along the seashore, particularly on the Gulf Coast where it is known as the dog fly. It lays its eggs in piles of marine weeds on the beaches and is a serious pest in late summer and early fall. Larval development takes 8 to 30 days or more, depending on temperature. The stable fly is not considered an important agent in mechanical transmission of organisms causing intestinal diseases. It does not breed in human excrement and is not commonly attracted to feces or garbage. It is therefore, less likely to pick up germs of diarrhea and other intestinal diseases.

Because of its blood-sucking habits, the stable fly has been suspected of transmitting a number of diseases but there is no proof that it is a biological vector of human disease. However, it is probably a vector of surra (a trypanosomal disease of horses and mules) and infectious anemia (a virus disease of horses). Stable fly larvae have been reported as causing myiasis of man and of domestic animals (*23*).

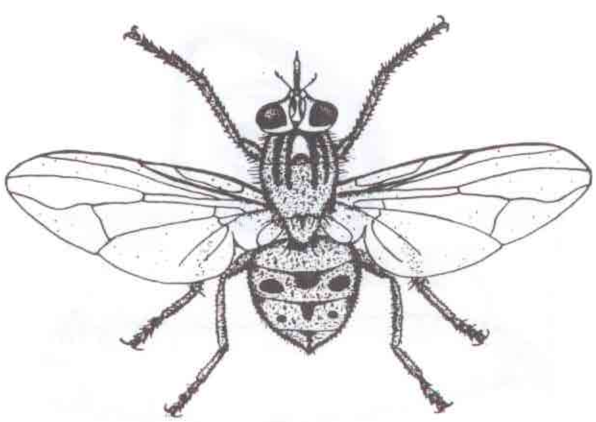


Figure 9. Stable Fly *(Stomoxys calcitrans)*

FALSE STABLE FLIES *(Muscina spp.)*

False stable flies are slightly larger and have heavier bodies than house flies, averaging about 8 mm long. These insects have a dull thorax and abdomen, with blackish markings, like the house fly, but differ in having a pale tip to the scutellum and the fourth wing vein gently curved and ending about at the wing tip (Figure 10). False stable flies breed in decaying animal and vegetable matter and are commonly found in scattered garbage. The larvae become carnivorous as they near maturity and destroy other fly larvae which they encounter. Larval development averages 15 to 25 days. The adult fly enters houses frequently and is attracted to human foods, including meat, fruit, and vegetables. It is a vector of disease organisms and there are reports of cases of human intestinal myiasis which probably resulted from ingesting foods containing eggs of *Muscina* (*18, 23*).

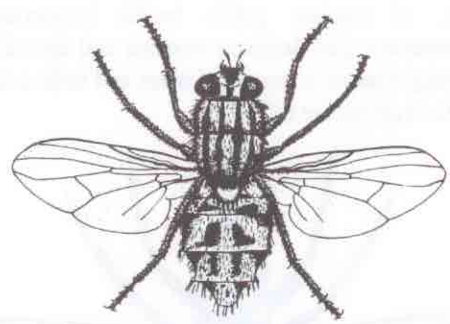


Figure 10. False Stable Fly *(Muscina stabulans)*

DUMP FLIES *(Ophyra* spp.*)*

Dump flies are shiny black flies, smaller than the house fly, with the fourth wing vein straight (Figure 11). Dump flies are widely distributed throughout the United States and are frequently abundant in cities. They are often found in fly trap collections, particularly those set near garbage disposal sites, hence their common name. Greenberg (*18*) reports that they enter homes, privies, and slaughterhouses and that their larvae develop in human and animal excrement, kitchen wastes, and animal carcasses. Second and third stage larvae are predaceous on other fly larvae and may help reduce populations of house fly larvae.

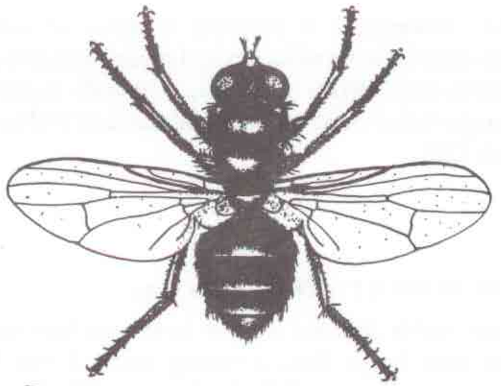


Figure 11. Dump Fly *(Ophyra leucostoma)*

TSETSE FLIES *(Glossina spp.)*

Tsetse flies are found in tropical and subtropical Africa. They vary in size from that of a house fly to that of a flesh fly, are usually brownish in color, and have a blood-sucking type of proboscis similar to that of the stable fly. The arista of the antenna has branched hairs on the upper side. The wing is remarkable in having the discal cell shaped like a meat cleaver, and is often called the "cleaver cell" (Figure 12). Tsetse flies are biological carriers of trypanosomes which cause two forms of African sleeping sickness (Gambian in West Africa and Rhodesian in East Africa) in man and nagana in cattle and in many types of hoofed animals. These insects are, therefore, of greatest public health importance in causing sickness and death in humans and animals, and in depriving man of a source of meat and milk and draft animals for agriculture (*37, 41*).

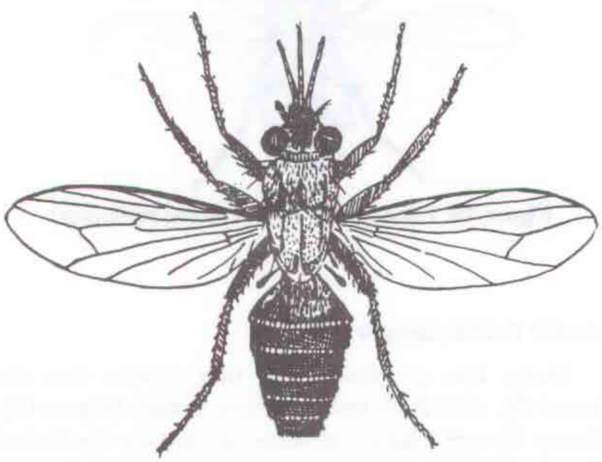


Figure 12. Tsetse Fly *(Glossina palpalis)*

FLESH FLIES (Family Sarcophagidae)

Flesh flies resemble the house fly in general appearance, but usually are larger and differ in having three dark longitudinal stripes on the thorax, a checkerboard pattern of grayish and dark spots on the abdomen, and the tip of the abdomen usually reddish-brown. The fourth wing vein is sharply angled and ends before the wing tip (Figure 13). There are hundreds of species of flesh flies in the family Sarcophagidae. They are commonly called flesh flies because the larvae of most species breed in meat, often in animal carcasses. Probably many of the cases of intestinal myiasis occur following the eating of meat, cheese, fish, and other foods left exposed on which flesh fly larvae were developing (*23, 24, 57*) Flesh flies are unusual in that the females deposit living larvae rather than eggs. Some species breed prolifically in animal excreta, especially in dog stools, and may be very abundant in urban communities. They do not enter homes nearly as often as house flies. When they do, they are often found in kitchens and bathrooms. The females are strongly attracted by the scent of foods such as fish and meat and of human excrement. They have been observed depositing larvae in containers with fecal samples in some laboratories, which has led to false reports of human intestinal myiasis (Figure 14). Some species of flesh flies in the genus *Wohlfahrtia* cause cutaneous myiasis in humans and are major pests at mink and fox farms, killing newborn or young animals (*24*).

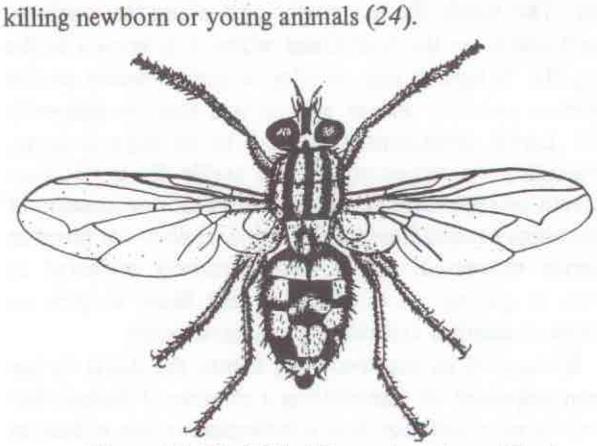


Figure 13. Flesh Fly *(Sarcophagula occidua)*

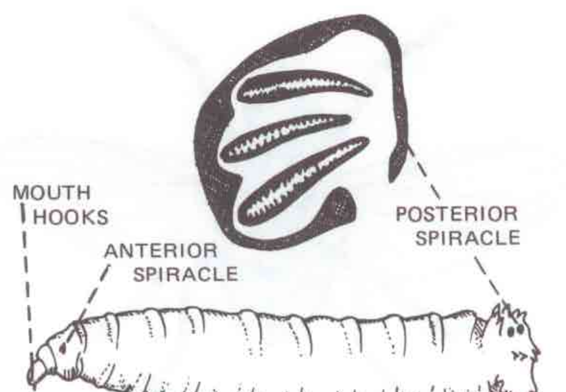


Figure 14. Flesh Fly Larva *(Sarcophaga haemorrhoidalis)*

BOTTLE FLIES AND BLOW FLIES
(Family Calliphoridae)

These flies lay their eggs upon animal carcasses and meat products causing them to swell, "bottle," or "blow" with maggots. Many of the adult flies have the shiny color of blue or green bottles. They are common in most urban areas and are often abundant about garbage dumps, abattoirs, and meat processing plants. They have long flight ranges and a keen sense of smell which guides them to dead animals and other attractants, even when located in remote areas. They enter houses much less frequently than house flies. The developmental stages are the same as for the house fly. Although they usually deposit their eggs upon meat, they will oviposit upon a wide range of fresh and decaying plant refuse if meat is not present. Eggs may be deposited on living animals, although clean, healthy animals are rarely attacked. Upon emerging from the egg, the larvae feed for a short time upon the surface of the food near the egg mass, then bore into the less putrid material within. When fully developed, they leave the breeding material and burrow into the ground. The puparium is formed within a few days and emergence occurs from 3 to 20 days after pupation. Calliphoridae serve as mechanical vectors of disease organisms in the same way as do house flies. They have similar non-piercing mouthparts and feed in much the same way. However, since they enter homes and restaurants less frequently than house flies, they appear to have less opportunity for disseminating disease organisms to food. The larvae of many species cause animal and human myiasis (*20*).

BLUE BOTTLE FLIES *(Cynomyopsis cadaverina* and *Calliphora)*

Blue bottle flies are medium to large species, 10 to 15 mm long or more, with a dull thorax and shiny metallic blue, green or purplish abdomen (Figures 15, 16). They

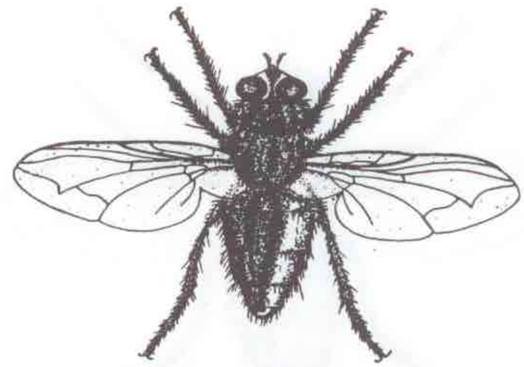


Figure 16. Blue Bottle Fly *(Cynomypsis cadaverina)*

frequently enter buildings to hibernate during the winter and emerge when buildings are heated, or on warm winter days, causing annoyance as they fly around with a loud, buzzing sound. Blue bottle flies require 15 to 20 days or more to develop from egg to adult. The adult flies are attracted to flowers, feces, overripe fruits, and other decaying vegetable matter as well as to sores on living animals. Blue bottle fly larvae may cause intestinal myiasis (*23, 57*).

GREEN BOTTLE FLIES AND BRONZE BOTTLE FLY
(Phaenicia spp. and others*)*

Green bottle and bronze bottle flies include many species in the genera *Phaenicia, Lucilia, Bufolucilia* and other less common genera. These insects occur from the Atlantic to the Pacific and throughout the world. Two of the species most commonly associated with man in the United States are the green bottle fly *(Phaenicia sericata)* (Figure 17) which has a shiny greenish thorax and abdomen, often with reddish or coppery reflections, and the bronze bottle fly (*Phaenicia cuprina*) (Figure 18) which has a shiny thorax and abdomen usually with coppery or bronzy reflections predominating over the greenish color. The life cycle is normally completed in 9 to 21 days with 4 to 8 generations per year. The eggs are

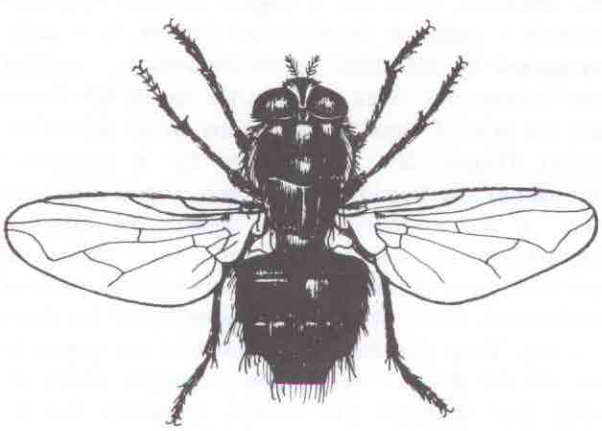


Figure 15. Blue Bottle Fly *(Calliphora vicina)*

Figure 17. Green Bottle Fly *(Phaenicia sericata)*

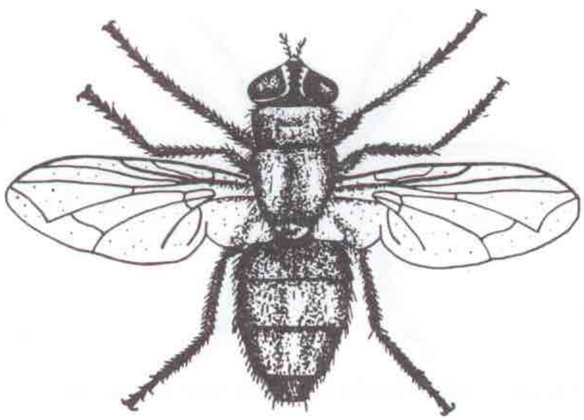


Figure 18. Bronze Bottle Fly *(Phaenicia cuprina)*

deposited on decomposing animal matter or in garbage containing mixtures of animal and vegetable matter. Females are strongly attracted to flesh and oviposition begins within a few hours after death of an animal. Fresh meat is often attacked within a few minutes after exposure. They also deposit eggs on wounds and occasionally cause intestinal myiasis (*57*). The average number of eggs produced at one time is about 180, although single females have been reported to deposit over 2,000. The optimum temperature for development of eggs is about 94° F, and hatching occurs in about 8 hours at this temperature.

The larvae complete their development in 2 to 10 days and then move away from the breeding medium and burrow in the soil. The larval stage may be greatly prolonged if temperatures are low, and these flies normally overwinter as full grown larvae in the soil. Pupation occurs within 3 days if temperatures are favorable, the pupal stage lasting 3 to 6 days under warm conditions. The adults may successfully emerge through several inches of earth (half of the flies emerging from puparia buried under 3 feet of loose soil reached the surface in experiments). Adults mate and deposit eggs 5 to 9 days after emergence. The green bottle flies are most active on warm sunny days. They are attracted to garbage (particularly where it contains mixtures of meat and fruit) plant juices, and nectar. They are often seen in large numbers on shrubbery, leaves of cucumbers and other melons, and on other plants. At times, particularly in the spring and fall, they enter houses and restaurants where they usually attract attention because of their buzzing flight. They may fly 10 miles from their breeding places within a few days. Favored nighttime resting places include trees, bushes, and sides of buildings.

BLACK BLOW FLY *(Phormia regina)*

The black blow fly has a shiny black thorax and abdomen with metallic blue-green luster. The setae on the top of the thorax are noticeably shorter than in other calliphorid flies and the mesothoracic spiracle (on the side of the mesothorax behind the head) is brick-red (Figure 19). This species occurs throughout the United States and is most abundant in the early spring. In the southern part of the United States it may be uncommon in summer, but is active on warm days throughout the winter. It is a mechanical carrier of organisms causing diarrhea and dysentery (*18*). It is a common producer of myiasis in sheep and cattle in the southwestern United States where it is found in wounds, castration incisions, and dehorning incisions. The life cycle requires 10 to 25 days or more and is generally similar to that of the green bottle flies. The eggs are laid in masses in animal carcasses or in the edges of wounds in living animals. Larvae may occur in great numbers in animal carcasses or in paunch contents of slaughtered animals. They also breed abundantly in garbage. The larval stage requires 4 to 15 days, the pupal stage 3 to 13 days, and the adults begin depositing eggs 7 to 17 days after emergence. The adults are strong flyers and have an effective flight range of 6 to 10 miles, but have been reported to disperse as far as 28 miles (*51*). In the north they overwinter as full grown larvae, but in the south, as adults.

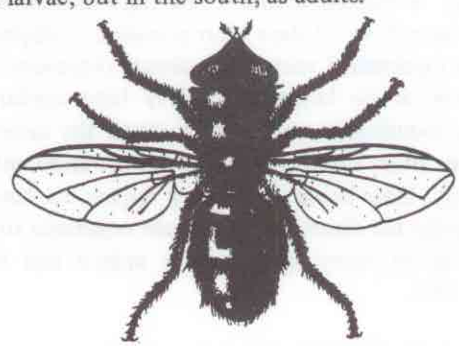


Figure 19. Black Blow Fly *(Phormia regina)*

CLUSTER FLY *(Pollenia rudis)*

The cluster fly is slightly larger than the house fly and the abdomen often has a slightly metallic reflection beneath a pollinose checkerboard pattern. It is easily recognized by the thick, yellowish-to-brassy, crinkled hair between the black setae on the top of the thorax and the tufts of these yellowish hairs on the side of the thorax (Figure 20). The cluster fly is distributed throughout the Northern Hemisphere and is very common in the northern United States. The eggs are deposited in the soil and hatch in about 3 days. This species is most unusual in that the larvae are parasites of earthworms, within which they feed and grow for about 2 weeks. They then leave the earthworm and pupate in the soil for about 2 weeks. Newly emerged adults are often most abundant after rainfall, suggesting that the adults can burrow from their puparia to the surface

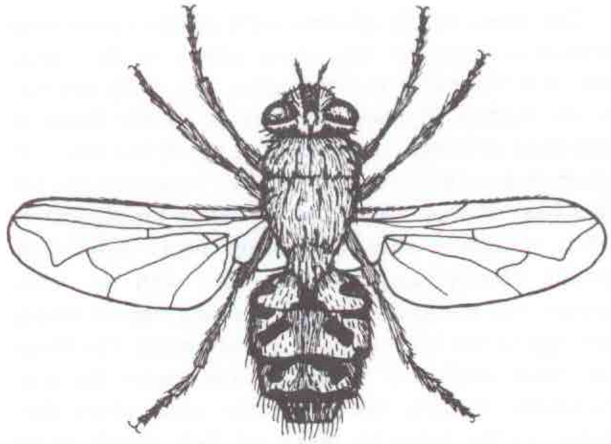


Figure 20. Cluster Fly *(Pollenia rudis)*

easier when the soil is soft and moist. There are probably 4 generations or more a year in the United States.

Cluster flies derive their name from the fact that the adults enter buildings in the fall to hibernate and accumulate in clusters in closets, attics, and unused rooms. They may be concentrated in open ceilings or walls, or may crawl behind window casings, mouldings, loose wallpaper, pictures, or furniture. During mild weather in the winter or early spring, or if a cold building such as a church is heated for Sunday services, they move about sluggishly, often with a loud buzzing noise, thus attracting attention to their presence. They are not of direct public health importance, but they may be a nuisance in buildings where they hibernate. In hospitals in northern United States there have been many complaints, for example, of cluster flies in operating rooms. The flies apparently entered these rooms through small openings around air ducts or electric fixtures from the cold attic above.

SCREWWORM FLIES *(Cochliomyia spp.)*

Screwworm flies are slightly larger than the house fly and have a bright yellowish face and a shiny, blue-green thorax and abdomen. The thorax has 3 dark longitudinal stripes and the mesothoracic spiracle is white (Figure 21). The primary screwworm larva (*Cochliomyia hominivorax*) is an obligatory parasite responsible for most of the cases of screwworm infestations in animals and man in the United States and in Latin America. The adults are rarely collected in ordinary fly traps. The secondary screwworm larva (*Cochliomyia macellaria*) is a scavenger and garbage feeder. The adults are often abundant in fly traps in the southern United States (*54*). The differences between the adults of these two species are minute and have been described by Hall (*20*) and James (*23*), but the differences between the larvae are easily seen. The larval tracheal trunks are deeply pigmented in the primary screwworm and less so in the secondary screwworm. The screwworm is the larva, or

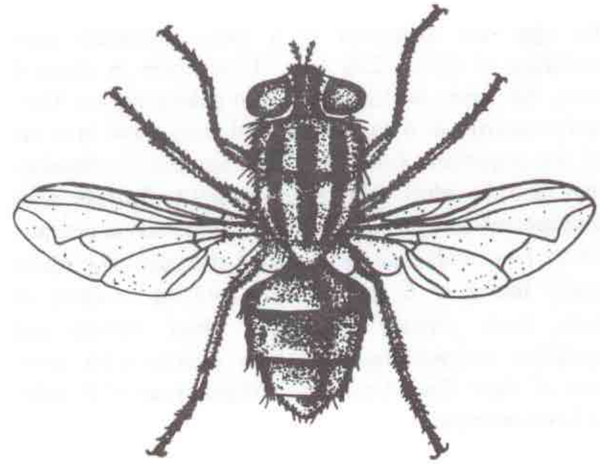


Figure 21. Secondary Screwworm *(Cochliomyia macellaria)*

maggot, of the screwworm fly. The taper of the larva's body and the rings of spines that encircle it somewhat resemble a wood screw, hence its common name.

The primary screwworm (*Cochliomyia hominivorax*) is a tropical and subtropical species which is widespread in Latin America. Formerly it occurred throughout the year in southern Florida and Texas, but extended its range northward by flight and on shipments of domestic animals so that it occurred by fall as far north as Virginia, Iowa, and California. The primary screwworm is strictly parasitic, attacking only clean fresh wounds. It parasitizes cattle, sheep, goats, man and other animals. Infestations of 20 percent of the livestock have been reported in some areas, with mortality reaching 20 percent of those infested. In 1935, there were 1,200,000 cases in livestock and 55 cases in man in Texas alone. However, by use of the sterile-male technique, beginning in 1958, the primary screwworm was eradicated from the United States east of the Mississippi River. Eradication west of the Mississippi is more difficult because of reintroduction from Mexico (*15, 30*). The eggs of the primary screwworm are laid in shingled batches of 10 to 400 eggs in or near wounds. They hatch in 11 to 21 hours and the larvae penetrate the tissues, leaving their posterior ends exposed to the air. Feeding is completed in 4 to 8 days, after which they drop to the ground and enter the soil to pupate. The average life cycle under summer conditions requires about 24 days. Adults seem to be less active than other Calliphoridae but they have a recorded flight range of 9 miles (*30*).

The secondary screwworm (*Cochliomyia macellaria*) is very similar to the primary screwworm in appearance. It occurs throughout the United States, but is seldom abundant in the north. This species does not infest living tissue, but it will infest wounds where it feeds upon the dead tissues. It is frequently involved in the "blowing" of meat in shops and homes, and may be of economic importance in this connection especially in abattoirs.

The eggs are deposited in a loose yellowish mass consisting of 40 to 250 eggs. They hatch in about 4 hours, the larvae feeding upon dead animal tissues. They reach maturity in 6 to 20 days and then crawl into the soil for pupation. The total time required for development into the adult stage ranges from 9 to 39 days, with development being most rapid in a warm, humid climate. Ten to 14 broods may be produced annually. The adults usually live 2 to 6 weeks. They feed on a variety of foods, from garbage to nectar. Dead animals and vegetation surrounding them have swarms with thousands of these flies. A maximum flight range of 15 miles has been recorded.

BOT FLIES
(Families Cuterebridae, Oestridae, and Gasterophilidae)

Bot fly larvae cause myiasis in many kinds of domestic animals and in man. These flies are in three different families, but the more important species can be discussed together. The human bot fly (*Dermatobia hominis*) (Figure 22) occurs in South and Central America, and in Mexico. Its larvae parasitize birds and mammals, including man. The adult fly does not seek its host directly but uses as a vector some other species of insect or arachnid (as *Psorophora* mosquitoes, domestic flies, and ticks). The female captures a vector species, glues her eggs to it, and then releases it. When the vector alights on a warmblooded animal, the eggs of the bot fly hatch and the larvae penetrate the skin. Development requires from 50 to 100 days after which larvae emerge from the host, drop to the ground, and pupate. The rabbit and rodent bots (*Cuterebra* spp.) are able to cause nasal and dermal myiasis in man as well as to parasitize their normal hosts.

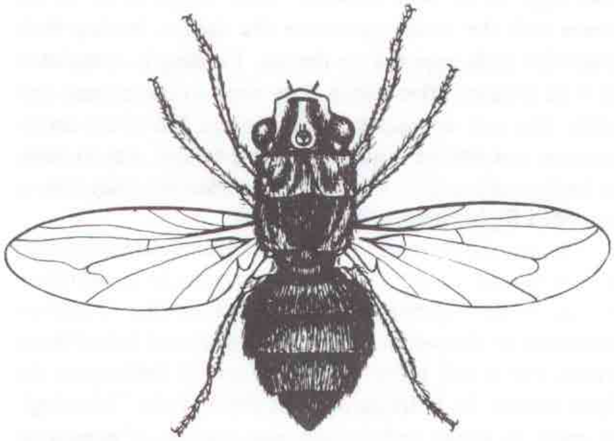


Figure 22. Human Bot Fly *(Dermatobia hominis)*

The sheep bot fly (*Oestrus ovis*) usually causes nasal myiasis in sheep but may cause myiasis of the human eye. It is worldwide in distribution. The cattle bot flies or ox warbles (*Hypoderma* spp.) are usually found in tumorous swellings on the backs of cattle, but they may cause myiasis in horses and man. The larvae of horse bot flies (*Gasterophilus* spp.) usually live in the alimentary tracts of horses, asses, and related hosts. After completing development, they pass out with the feces, pupate, and the adults emerge. The adult female fastens her eggs to the hair or lips of a host animal. The larvae are either swallowed or they burrow under the skin, eventually reaching the alimentary canal where they fasten to the lining by means of their mouth hooks (*23, 24*).

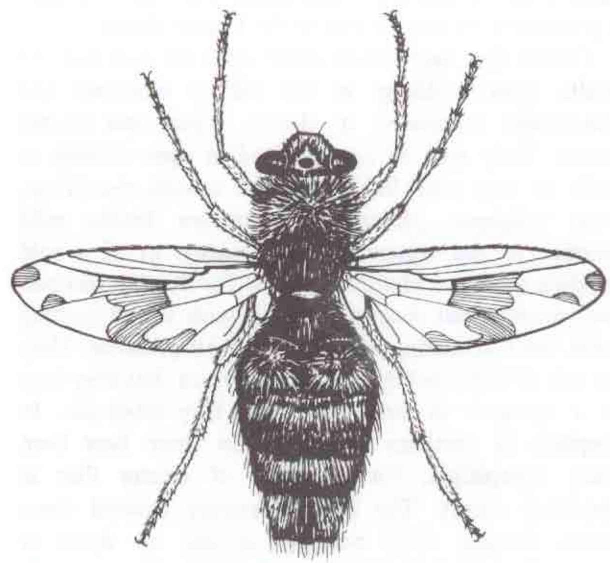


Figure 23. Horse Bot Fly *(Gasterophilus intestinalis)*

SOME FLIES OF LESSER PUBLIC HEALTH IMPORTANCE

MIDGES (Families Chaoboridae and Chironomidae)

Midges are tiny flies, usually 1 to 4 mm long, which breed in water or damp soil. Adult midges do not bite. However, they may occur by the millions and be most annoying. It is sometimes difficult to keep them out of people's eyes and nostrils, particularly when the midges are attracted to lights. The Clear Lake gnat, a species of Chaoborid midge, is a serious pest in parts of California (*24*). Adult midges cause trouble by getting into fresh paint, getting into paper factories and ruining sheets of paper, and staining the sides of painted buildings. Chironomid midge larvae are sometimes found in water reservoirs and are carried throughout the distribution system. Many a householder has been disturbed when she found "bloodworms", reddish chironomid larvae, in a glass of water. Mason (*34*) has published keys to many chironomid larvae.

BITING GNATS, PUNKIES, NO-SEE-UMS
(Family Ceratopogonidae)

Some of the ceratopogonid midges in the genera *Culicoides* and *Leptoconops* are vicious biters. *Culicoides* are tiny flies, about the size of the head of a pin, generally with spotted wings and reduced wing venation (Figure 24). Their bites often cause intense pain, for many people worse than that of a mosquito. Important pest species include *Culicoides melleus, C. hollensis,* and *C. furens* of the East and Gulf Coasts and *Leptoconops torrens* and *L. kerteszi* in the south and west. Several species of *Culicoides,* called "punkies," "no-see-ums," or "sand flies," are so small that they can crawl through the ordinary 16-mesh window screen and be serious pests at summer camps, shore restaurants, and bathing beaches. In this country *Culicoides variipennis* transmits the virus causing blue tongue of sheep. Outside the United States *Culicoides* spp. are vectors of human filarial worms (*Mansonella ozzardi* and *Acanthocheilonema perstans*) and two types of worms (*Onchocerca cervicalis* of horses and mules and *O. gibsoni* affecting cattle) causing animal diseases (*14, 24, 33*).

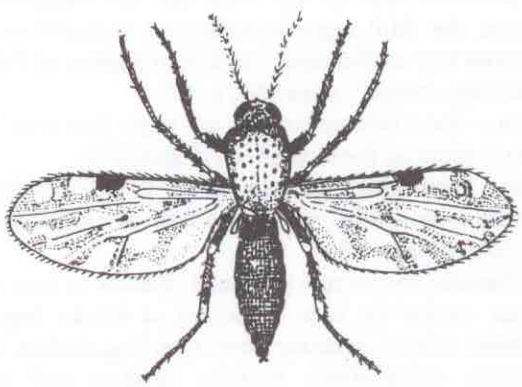


Figure 24. Biting Midge *(Culicoides furens)*

BLACK FLIES (Family Simuliidae)

Black flies (Figure 25) are nearly worldwide in distribution and second only to mosquitoes as blood-sucking pests of man. They are small (2 to 5 mm long), stout-bodied flies with short antennae, wings with the anterior veins well developed, and a "humped" thorax which has given them the common name "buffalo gnats." Both sexes suck nectar from flowers and most females suck blood. The eggs are laid in or near flowing water and the larvae and pupae are found attached to submerged rocks, sticks or vegetation. The adult emerges from the pupa in a submerged cocoon and floats to the surface of the water in a bubble of air. Many species mate soon after emergence.

Black fly bites are painless at first, but later become swollen, hard, and painful, sometimes infected from scratching. Females of certain species attack man, while others confine themselves to mammals or birds. They swarm around exposed parts of the body, particularly the head, and get into the nose, eyes, ears, and mouth. Heavy attacks may be fatal to man, cattle, horses, and poultry, possibly from toxemia, anaphylactic shock, or suffocation brought about by inhalation of large numbers of swarming insects. Several species transmit tularemia in North America, human onchocerciasis (blinding filariasis due to *Onchocerca volvulus*) in Africa and Central America and bovine onchocerciasis in Europe and Australia (*21, 26, 59*). Other species transmit deadly protozoa (*Leucocytozoon*) to ducks and turkeys (*24*).

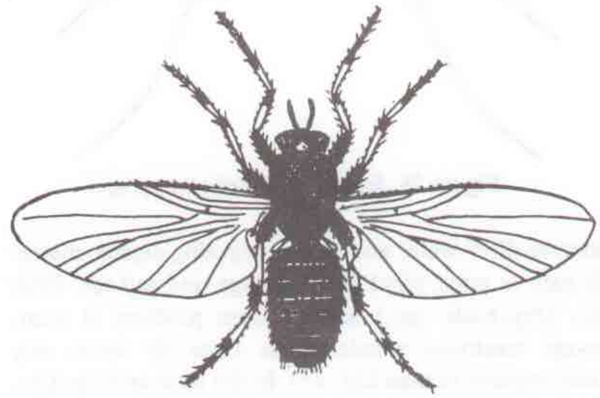


Figure 25. Black Fly *(Simulium venustum)*

SAND FLIES, FILTER FLIES AND MOTH FLIES
(Family Psychodidae)

The family Psychodidae contains small fuzzy flies with hairy wings divided into two distinct groups: the filter and moth flies in the subfamily Psychodinae, whose females are not bloodsuckers, whose wings are held rooflike over the body, and whose larvae are commonly aquatic; and the sand flies in the subfamily Phlebotominae (Figure 26) whose females are bloodsuckers, whose wings are not held rooflike over the body, and whose larvae are typically terrestrial. The filter and moth fly group is widely distributed and abundant in most parts of the United States. Adult moth and filter flies are often found on bathroom and kitchen windows. Some common sources of domestic infestations are dirty garbage containers, water traps in plumbing fixtures, and accumulated gelatinous debris around the edge of sinks and wash basins built into counter tops. A common American moth fly is *Psychoda alternata.* Outdoors the larvae may be found in collec-

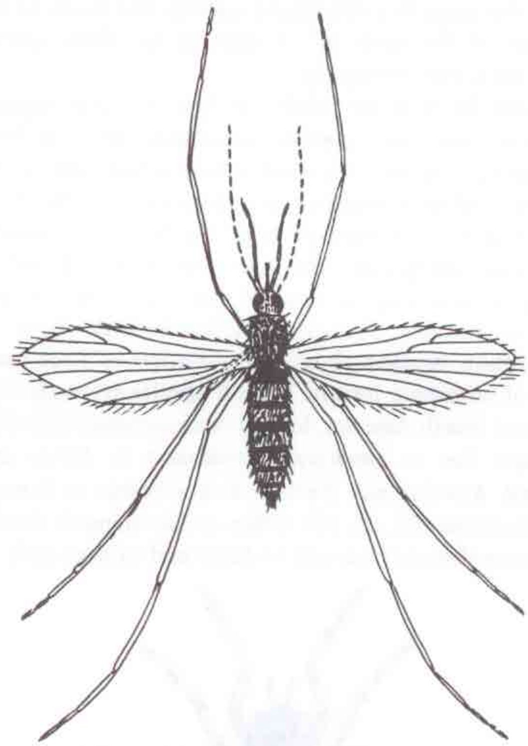


Figure 26. Sand Fly *(Phlebotomus* sp.)

tions of dirty water and in decomposing organic materials such as grass, plant litter, sewage, and garbage. Filter flies (*Psychoda* spp.) are a serious problem at many sewage treatment plants. Some filter fly larvae may cause myiasis in man (*23, 45*). In the Near and Far East, North Africa and Central and South America, sand flies in the genera *Phlebotomus* and *Lutzomyia* may bite man and transmit organisms causing sandfly fever, several types of leishmaniases and bartonellosis (*24, 31, 62*). Bloodsucking sandflies are comparatively rare and are not known to transmit human diseases in the United States. Rosabel and Miller (*48*) have published a key to the 9 species of bloodsucking sandflies in the genus *Lutzomyia* (formerly included in the genus *Phlebotomus*) in the United States. The adults have been found most often in hollow trees or in rodent burrows, and their immature stages may breed there. Recent taxonomic work places the important species of sand flies in Europe, Africa, and Asia in the genera *Phlebotomus* and *Sergentomyia* and the important, man-biting American species in the genus *Lutzomyia* (*31, 62*).

CRANE FLIES (Family Tipulidae)

Crane flies, which resemble mosquitoes superficially, are slender flies with long legs. They differ in having a V-shaped suture on the thorax and no scales on the wings. They breed in water, moist soil, and damp, rotting vegetation. Many species 12 to 25 mm or more long are attracted to lights and enter homes, thus causing complaints about invasion by "giant mosquitoes" even though they are unable to bite man.

HORSE FLIES AND DEER FLIES (Family Tabanidae)

Horse flies and deer flies rival mosquitoes and black flies as annoying pests of man and domestic and wild animals. Many are vicious biters and can inflict painful wounds that itch for days. Only the females suck blood; the males feed on plant nectar. In most parts of the United States deer flies (*Chrysops*) are more serious pests of man than horse flies (*Tabanus* and *Hybomitra*) which are major pests of cattle and horses. However, along the Atlantic coast, the salt marsh greenheads (*Tabanus nigrovittatus*) are vicious, human pests, particularly at bathing beaches. Other species of horse flies may be serious bloodsucking pests elsewhere. Many species deposit their eggs on vegetation near water and their larvae develop in damp soil or water but some develop in dry pasturelands. In general, most species have one generation a year, but some of the larger species such as the black horse fly (*Tabanus atratus*) (Figure 27) may take two or three years for development.

The family Tabanidae contains small to very large flies, 6 to 33 mm in length, generally recognized by the five posterior cells on the wing and the 3-segmented antenna, the third segment subdivided as shown in the "Pictorial Key to Principal Families of Diptera of Public Health Importance", Appendix, p. 42.

Horse flies (*Tabanus*) usually are larger than deer flies and lack spurs on the hind tibiae. (Figure 27).

Deer flies (*Chrysops*) average 6 to 12 mm long, generally have spotted wings, and have two spurs on the hind tibiae (Figure 28).

Tabanidae are vectors of several diseases of man and animals caused by such organisms as viruses (equine infectious anemia, vesicular stomatitis, hog cholera, and California encephalitis), bacteria (anthrax and tula-

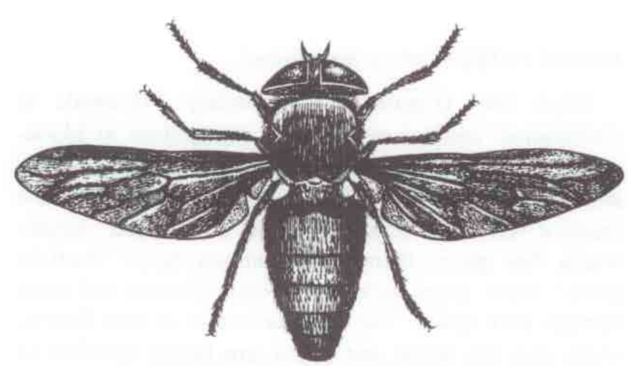


Figure 27. Horse Fly *(Tabanus atratus)*

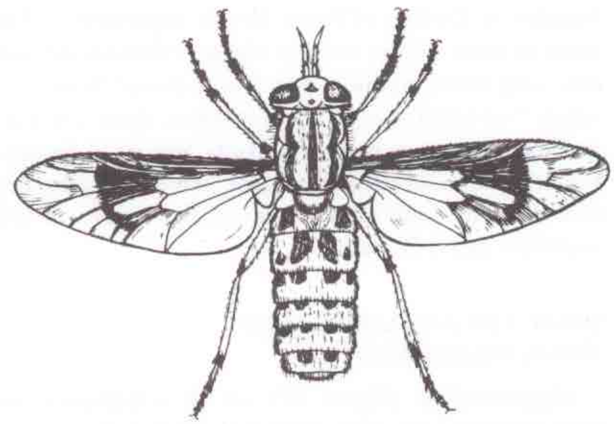


Figure 28. Deer Fly *(Chrysops discalis)*

remia), rickettsiae or rickettsia-like organisms (Q-fever and anaplasmosis), trypanosomes (surra), and filarial worms (loasis and elaephorosis). In the United States deer flies, particularly *Chrysops discalis* (Figure 28), are important in the mechanical transmission of tularemia in the West where the disease is sometimes known locally as deerfly fever. Both deer flies and horse flies may serve as mechanical carriers of anthrax bacteria from domestic animals to man, particularly in southern United States (*24, 43*).

SNIPE FLIES (Family Rhagionidae)

Snipe flies (Figure 29) breed in water or soil. Their larvae are predaceous. Members of the genera *Atherix, Rhagio, Spaniopsis,* and *Symphoromyia* bite man. They have not been shown to be the vectors of any human disease.

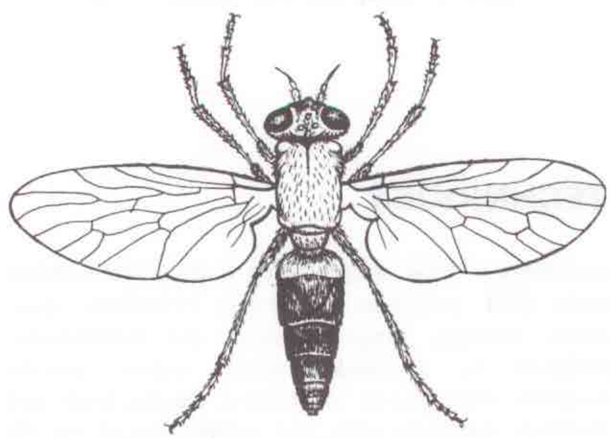


Figure 29. Snipe Fly *(Symphoromyia)*

SOLDIER FLIES (Family Stratiomyiidae)

Soldier flies in the genus *Hermetia* breed in decaying vegetation and organic materials and may cause intestinal myiasis in man. These flies may be an important check on populations of domestic flies since the soldier fly larvae tend to keep material in privy pits soft and moist, an unfavorable habitat for house fly larvae (*28*).

VINEGAR FLIES AND FRUIT FLIES
(Family Drosophilidae)

Vinegar and fruit flies (Figure 30) breed in decaying fruit and may suddenly become numerous in a house. The usual sources in the home are overripe fruit and dirty garbage containers. The fruit fly (*Drosophila melanogaster*) belongs in this family. Much of the knowledge of the science of genetics is based upon studies with this insect. Some species of *Drosophila* cause intestinal myiasis in man (*23*).

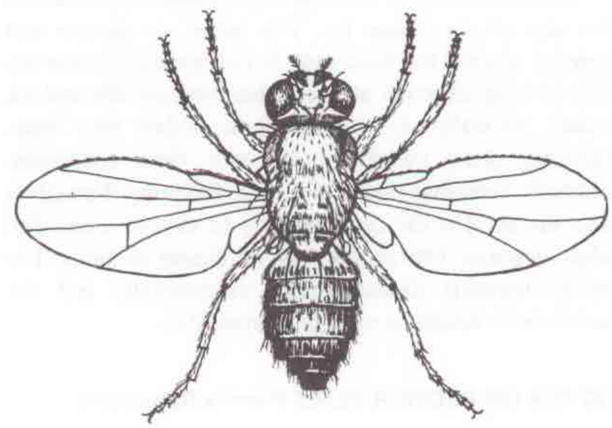


Figure 30. Fruit Fly *(Drosophila)*

EYE GNATS (Family Chloropidae)

Eye gnats are tiny, shiny black flies with reduced wing venation. The important genus *Hippelates* has a curved, blackish spine on the hind tibia (Figure 31). Keys to the genus *Hippelates* have been published by Sabrosky. Eye gnats are often very abundant in the

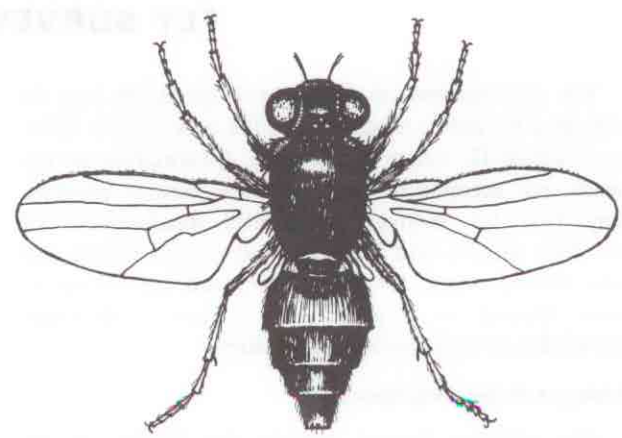


Figure 31. Eye Gnat *(Hippelates)*

southern United States. They swarm about the face and eyes and rasp the eye membranes with their mouthparts. In the southern United States and in the Coachella Valley in California, eye gnats transmit organisms causing epidemic pinkeye, or conjunctivitis. Sometimes so many children are affected that the schools are actually closed for a week or more. The larvae of eye gnats breed in loose soil, frequently over vast areas of rich agricultural land, which makes control very difficult. The life cycle is completed in from two to four weeks (*1*).

CHEESE MAGGOT AND RELATED FORMS
(Family Piophilidae)

The cheese skipper or maggot (*Piophila casei*) is about the size of the house fly. The larvae are slender and pointed toward the head end. At one stage the larvae are able to skip as much as ten inches horizontally and six inches vertically by curving their bodies into rings, fastening their mouth hooks onto their abdomens, suddenly releasing their holds, and throwing themselves into the air. The life cycle requires 12 days or more. The adult deposits 140 to 500 eggs on cheese or hams. The adults transmit disease agents mechanically and the larvae cause intestinal myiasis in man (*23*).

HOVER OR FLOWER FLIES (Family Syrphidae)

Hover or flower flies are small to large flies which resemble bees or wasps. Many of them are conspicuously marked with yellow and black. The distinguishing family characteristic is a pigmented line, called a spurious vein, on the wing, as shown in the "Pictorial Key to Principal Families of Diptera of Public Health Importance." The larvae of some species breed in highly polluted water and have long breathing tubes which have caused them to be called "rat-tailed maggots." Sometimes these are very abundant at sewage treatment plants. Species of *Eristalis* and *Helophilus* occasionally cause human myiasis. Telford (*61*) has published a key to the species of the important genus *Eristalis*.

SHEEP KED AND LOUSE FLIES
(Family Hippoboscidae)

Hippoboscidae (Figure 32) are all ectoparasitic on birds and mammals. The sheep ked, *Melophagus ovinus*, is often found crawling on the bodies of sheephandlers and may inflict a painful bite. It is suspected of being a vector of Q fever in Canada. Bird louse flies, such as *Pseudolynchia canariensis* from the pigeon, may also be found on and biting man (*24*).

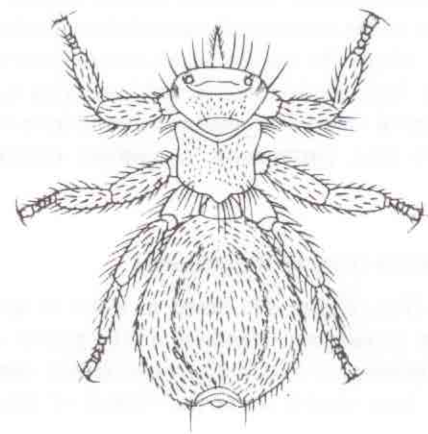


Figure 32. Sheep Ked *(Melophagus ovinus)*

FLY SURVEY TECHNIQUES

The effectiveness of fly control operations may be indicated by public reaction, but the only reliable index is an actual fly count in the field. Information on the needs and accomplishments of a fly control program may best be obtained by careful measurement of breeding sources and fly populations both before and after control work. Effective survey and control operations depend to a great extent upon a thorough knowledge of fly population dynamics.

POPULATION DYNAMICS

The primary factors limiting the density of fly populations are the physical environment, including availability of food, water, shelter, and suitable breeding media (*18*); parasitism by viruses, rickettsiae, spirochetes, bacteria, fungi, protozoa, and roundworms; predation by centipedes, mites, spiders, pseudoscorpions, other insects, amphibians, reptiles, birds, and mammals–especially man; and competition of one fly with another for the benefits of the environment.

Fly populations are modified by reproduction, which is often tremendous; mortality, which is also enormous; and migration, which varies with the nature of environmental pressure. Many more flies are born than can survive. The numbers of flies an area can support is limited by the nature of the physical and biological environment. Excess flies must either migrate or die (*58*).

> Example: Block "A" has an environment capable of supporting 1,000 house flies and of producing 125,000 additional flies every 2 weeks. The newly developed flies face severe competition for food, and water, shelter. They are killed by disease and predation. Some migrate and compete with neighboring fly populations. The small percentage surviving mate; and the females compete for suitable media in which to lav their eggs. Another 125,000 eggs hatch and the great struggle begins anew.

Many fly control measures tend to kill only that excess of population which would die in a short time. If, for instance, Block "A" is sprayed with insecticide the fly population will be lowered, but actually the insecticide only kills many flies which would die in a short time. Individuals surviving will soon rebuild the population. Long term fly control for Block "A" must either remove enough food, water, and shelter that fewer than 1,000 flies can survive or must remove enough breeding material that fewer than 1,000 flies can be produced. This "long term" control technique is called environmental sanitation.

APPRAISAL TECHNIQUES

Fly surveys are made to determine the species of flies, and to furnish an index as to fly abundance, in an area. By looking up the ecology of common species in reference literature, personnel can determine what larval habitats should be searched out and eliminated. By comparison of successive surveys they can evaluate control effectiveness. Since it is not possible to determine the precise number of flies, surveys are designed to give an index of the population. A good survey will also show relative numbers of the various species. The method used must be reliable enough that successive surveys will be comparable. Reliability is limited by the skill of the surveyor, the errors that are inherent in the methods, and fluctuations of fly population in response to environmental conditions. Evaluation of control operations is greatly hampered by the coaction of control and environment. Survey methods must be modified to suit the ecology of the flies that are involved.

SURVEY METHODS FOR DOMESTIC FLIES

Flies of the families Muscidae, Sarcophagidae, Calliphoridae, and Drosophilidae are usually considered to be domestic flies. In determining fly populations and the need for control, ***adult surveys*** are usually more practical and reliable than ***larval surveys***. Consequently, all commonly employed techniques are related to adult populations (*50*). The most generally used methods are the insect net surveys, fly trap surveys, and the fly grill surveys. The insect net and fly trap surveys are used to determine the *kinds* of flies present in an area, whereas the fly grill surveys provide an *index* to the relative numbers of the various species in the fly population. None of these types of surveys gives an absolute *count* of the fly population present in an area.

INSECT NET SURVEYS

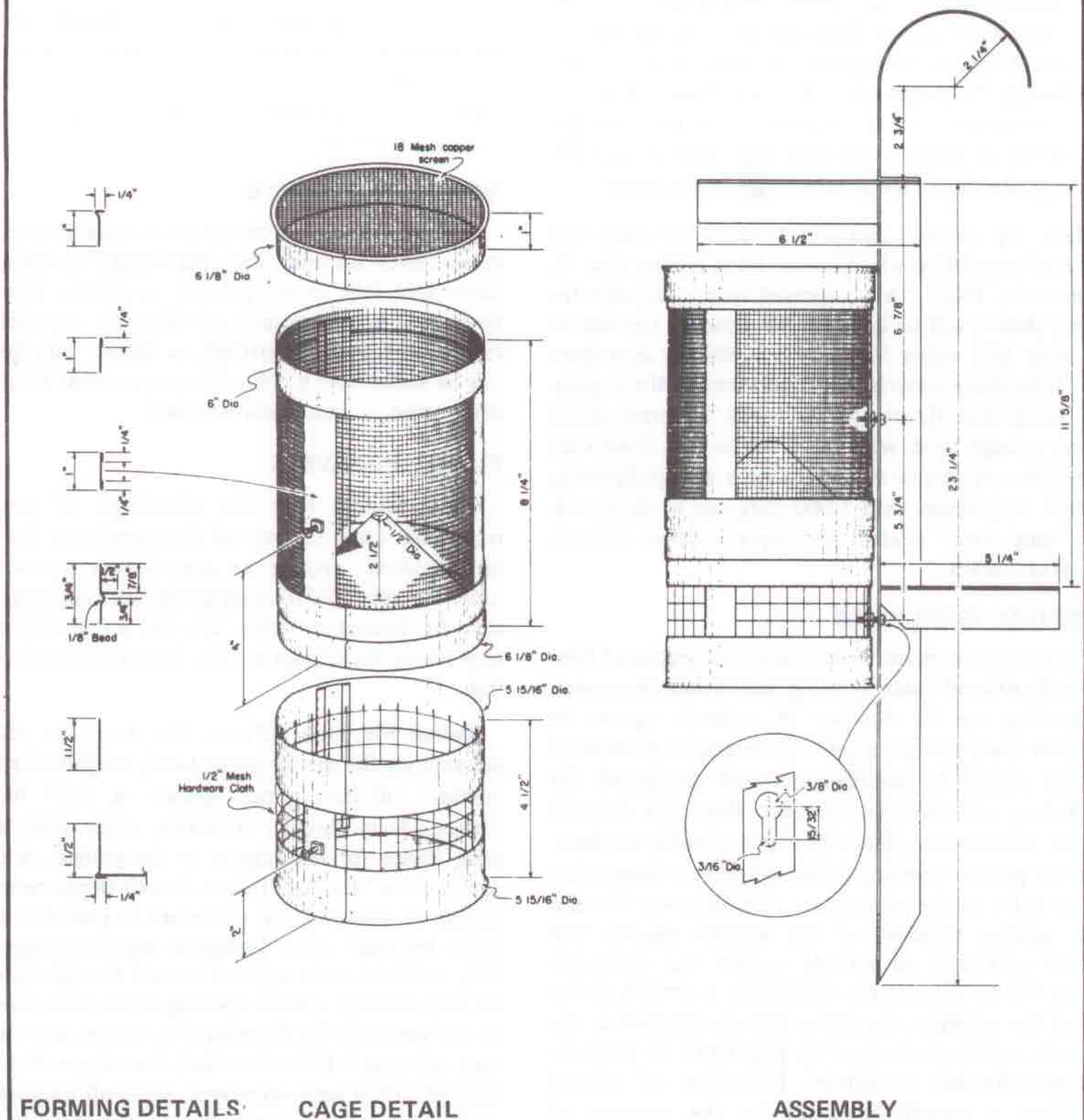
The standard insect sweep net is often used to make a quick survey for adult flies, particularly at open dumps, cattle feed lots, or in epidemic or disaster areas where there are large amounts of decaying vegetables and fruits, dead animals, garbage, or refuse. The specimens can be killed with a chloroform or cyanide killing tube, determined, counted, and recorded.

FLY TRAP SURVEYS

Trap surveys have the advantages of securing a reasonable cross section of the population for careful identification, making an approximate count of the relative numbers of the various species, and trapping flies alive for laboratory study. The two commonly used fly trap survey techniques are the baited trap and the cone trap.

Baited Fly Trap Surveys. Bait traps are useful for determining the species present and, roughly, the relative numbers of the various species. A good bait trap (Figure 33) is durable, attractive, easily used, and has some device for fastening it to the ground. A suitable sign such as "Do Not Touch, Health Department Test" should be attached. An attractant is placed in the pan under the trap. After feeding or depositing eggs on the bait, the flies move upward toward the light and enter the trap through a small opening in the cone. Since they do not generally fly downward to escape, and since the cone opening is difficult to find, few escape. Not all flies respond to the same attractant, so an all purpose bait is used: fish heads, chicken entrails, vegetables, and fruit. Traps are placed in different sections and in different types of blocks (slums, good housing, business, industrial, etc.) Flies are killed in chloroform jars, then identified and counted. Collections may be stored in boxes, such as ice cream cartons. Each collection should be labelled with date, location, method of collection, and name of collector. In extensive surveys a special form may be designed for recording data.

Fly Cone Surveys. Fly cones are used primarily to collect live flies for bacteriological and virological study. The fly cone (Figure 34), made of screen wire, is placed



Bands and vertical members: 24 ga. sheet metal
Stand: 1¼" x 1¼" angle iron
Carrying handle: 1/8" x 1" strap iron
Bolts: 1/8" x 3/4" round-head stove bolts
Spot-weld all bands, solder all screen and hardware cloth

Figure 33. Bait Trap for Collecting Flies

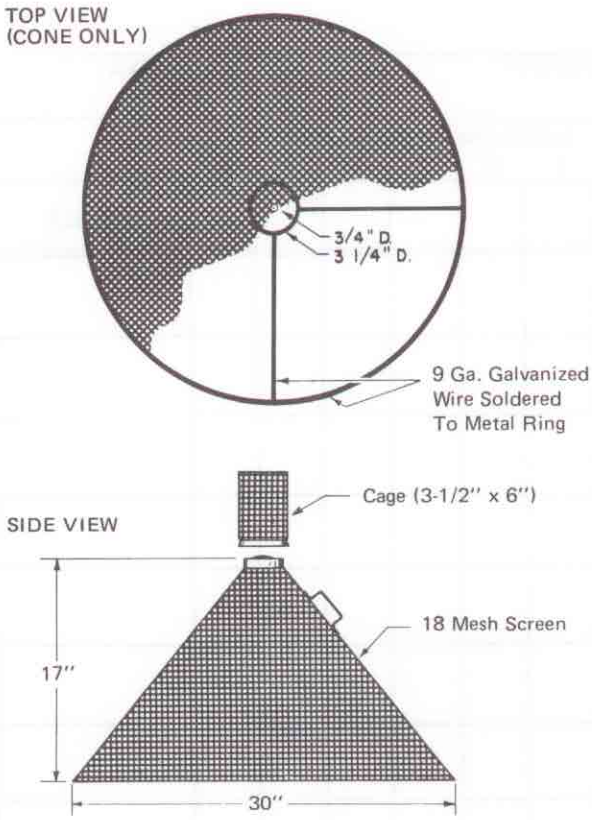


Figure 34. Fly Cone

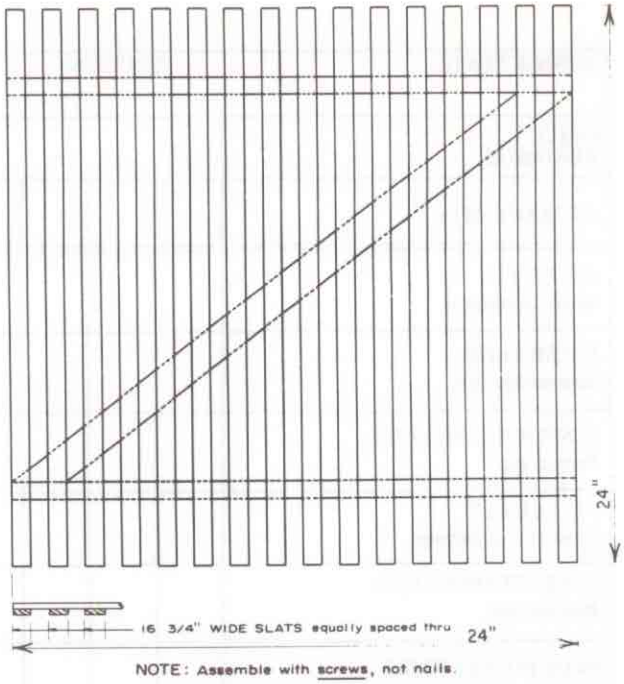


Figure 35. Fly Grill

over a natural attractant (garbage, manure, etc.), trapping flies beneath it. A dark cloth is thrown around the cone and the apparatus is carefully agitated. Attempting to escape, the flies move upward toward the light and enter the cage; then, the sliding door of the cage is closed and the collection is labeled. Flies may be taken to the laboratory for bacteriological and virological study.

FLY GRILL SURVEYS

Fly grills are widely used in modern evaluation of fly populations. Fly grill surveys are faster than baited trap or fly cone surveys and give a highly valid picture of the fly situation. The fly grill depends upon the tendency of flies to rest on edges, and so it presents many attractive resting sites. The grill (Figure 35) is placed over natural attractants (garbage, manure, etc.) and the number of flies landing on the grill during a 30-second interval is tabulated. When the grill is put down, the flies are somewhat disturbed and fly upward for a short distance. When all is again quiet, they come back down, alighting on the grill instead of the attractant. Record is made of the total number of flies and of the number of individuals of each species present. Use of the grill requires a high degree of familiarity with the species present. Consequently, flies must be trapped and sorted by the surveyor until he is able to recognize all common species instantly. If fly counts are so high that total counts become impracticable, the grill may be divided into halves, quarters, or sixths, with painted markings. At least one-sixth of the grill must be counted. A minimum of 10 counts is made in each block sampled, and the 5 highest counts are recorded on the grill record (Figure 36). This piece of equipment is often called the Scudder fly grill, for Dr. Harvey Scudder of CDC, who first developed this method of making adult fly surveys (*32, 66*).

RECONNAISSANCE SURVEYS

Reconnaissance surveys are ordinarily used as a supplement to fly grill surveys. They are made in vehicles or on foot by observing the abundance of flies in favored resting places, and recording densities as estimated grill readings. They provide data to guide control operations in areas lacking grill coverage; to facilitate rapid control in times of epidemic or disaster; to serve as post-treatment evaluations of space spray applications; and, to serve as preventive maintenance inspections during times of low fly density. Reconnaissance surveyors should be very familiar with fly grill survey methods.

FLY EGG COUNTS

These are used in some food sanitation surveys, such as in tomato products. Other food sanitation fly survey methods are outlined by the U.S. Food and Drug Administration (*64*).

TOWN & STATE:					SECTION:		BLOCK #:		DATE:		HOUR:
GRILL READINGS	Tabulate the five highest counts										
	1	2	3	4	5	6	7	8	9	10	
ATTRACTANTS											TOTALS
HOUSE FLY *Musca domestica*											
FLESH FLIES *Sarcophaga* spp.											
LESSER HOUSE FLIES *Fannia* spp.											
STABLE FLY *Stomoxys calcitrans*											
FALSE STABLE FLIES *Muscina* spp.											
BLUE BOTTLE FLIES *Calliphora & Cynomyopsis* spp.											
DUMP FLIES *Ophyra* spp.											
SECONDARY SCREW WORM FLY *Cocbliomyia macellaria*											
BLACK BOW FLY *Phormia regina*											
GREEN BOTTLE FLY *Phaenicia sericata*											
BRONZE BOTTLE FLY *Phaenicia cuprina*											
OTHERS											
TOTALS											
BLOCK AVERAGE:					HIGH COUNT:			INSPECTOR:			

HIGH COUNT: The highest count of the five high grill readings.

BLOCK AVERAGE: Total the five high grill readings and divide by five.

ATTRACTANTS:

A. Garbage (mixed)
B. Excrement
C. Fruits
D. Vegetables
E. Dishwater
F. Dead animals
G. Seafood wastes
H. Feeds
I. Bones
J. Decaying vegetation
K. Other

Figure 36. FLY GRILL RECORD

LARVAL SURVEYS

Larval surveys are commonly employed in mosquito control programs but have been seldom used in fly control activities. This circumstance is due primarily to difficulty in locating fly larvae and to the inability of most fly control personnel to identify them.

However, larval surveys are important. Such surveys serve to demonstrate the relative significance of available breeding media and to emphasize the importance of sanitation in fly control. Fly larval surveys, for example, have demonstrated in urban areas that dog stools are important sources in producing flesh flies and green bottle flies which are pests at backyard picnic tables.

Mosquito control personnel have learned to concentrate operations in watered areas which produce the greatest number of mosquitoes rather than to work an entire area. Fly control personnel can learn, likewise, to concentrate on those breeding areas which produce the greatest number of flies (*19*).

USE OF SURVEY INFORMATION IN CONTROL PROGRAMS

The success of fly control programs depends largely on close coordination of entomological surveillance and control activities. By comparing data from survey to survey it is possible to determine problem areas and to concentrate efforts to eliminate the most important breeding sites of flies. Primary emphasis should be given to environmental sanitation rather than insecticidal application. One of the best uses of survey data is in reports and publicity programs to make key officials and the general public more aware of program activities and to obtain their support. Entomological survey data can be used effectively in reports and newspapers, on the radio and television to show progress in refuse storage, collection, and disposal programs, neighborhood cleanup campaigns, and community organization activities.

SURVEYS FOR NONDOMESTIC FLIES

Surveys must be based upon a thorough knowledge of the ecology of the species involved. Some commonly employed techniques are: biting and landing rates of adult flies; special bait traps for flies attracted to certain animals, foods, or breeding materials; malaise traps with dry ice (solid carbon dioxide); light traps; and larval counts made from soil, mud, or uniform quantities of breeding materials. In some cases breeding materials of known quantity may be put out to attract egg-laying females, and emerging larvae are counted. Suitable survey techniques for nondomestic flies of public health importance are itemized in Table 4.

TABLE 4. SURVEY TECHNIQUES FOR NONDOMESTIC FLIES

Scientific Family Name	Common Name	Suitable Survey Techniques
Ceratopogonidae	Biting Midges	Larval count from around edges of fresh or brackish water; adult count from light trap or biting collections.
Chironomidae	Midges	Larval count from dredge samples of bottom mud; adult light trap count.
Chloropidae	Eye Gnats	Egg or liver bait trap for adult counts; larval count from organic debris.
Hippoboscidae	Keds & Louse Flies	Ectoparasite count from combings of sheep, birds, and other hosts.
Piophilidae	Cheese Maggots (Cheese Skippers)	Larval count from cheese and smoked meat destined for use as food.
Psychodidae	Sand and Filter Flies	Adult biting or landing rate; special bait trap employing attractant animal or castor oil; adult count from light trap or insect net collections.
Rhagionidae	Snipe Flies	Adult biting or landing rate; adult net surveys.
Simuliidae	Black Flies	Adult biting or landing rate; larval count from fast flowing streams.
Tabanidae	Deer and Horse Flies	Adult biting or landing rate; pyrethrum emulsion larval survey; adult count from malaise trap with carbon dioxide dry ice.

DOMESTIC FLY CONTROL BY ENVIRONMENTAL SANITATION

The control of filth-frequenting flies has been a major problem of health departments for many years. During the horse-and-buggy era, flies were tolerated as an unavoidable nuisance. Many people had privies in the backyards of their homes, relied on horses for transportation, and kept chickens, cows, pigs, or rabbits as a source of food. Fly breeding was so intense in manure that city ordinances were passed prohibiting the use of privies or the keeping of animals within the city limits. When flies were condemned as carriers of organisms causing typhoid fever and many other diseases, homes were screened and the use of the spray gun became widespread. Conditions improved when automobiles replaced horses on the street, but the migration of people from the farm to the city was in full swing. Living quarters became crowded, and environmental sanitation reached a low ebb. Refuse accumulated and the fly problem became acute. The synthetic organic insecticides were used effectively to control flies for some years; but, as resistance became a problem, it became increasingly obvious that emphasis must be placed upon environmental sanitation as the primary fly control method (*67*).

At the present time many people keep dogs for protection from intruders. These animals are usually kept in fenced backyards, where dog manure accumulates and fly breeding is intense. Modern fly control, therefore, involves both refuse control and environmental sanitation. Sewage and industrial wastes, while usually not the number one fly breeding source, can be major fly producers. Since some of these wastes are heavily laden with germs, or pathogens causing diarrhea and dysentery, they become important beyond their volume from the public health standpoint. Animal feeds and excrement, plus a large number of minor breeding sources, can add significantly to the fly population. These sources should be sought out and eliminated in order to have an effective fly control program.

REFUSE STORAGE

Sanitary refuse storage on all premises is the basic requirement for effective domestic fly control. At individual homes and small apartments, metal or plastic garbage cans are suitable for storing garbage or refuse. Garbage cans should be of heavy duty construction to prevent damage by collection personnel, rust-resistant, watertight, easy to clean, and easily handled by one man. They should have tightly fitting lids to exclude flies and recessed bottoms to prevent rusting, if made of metal. Ideally, all garbage should be placed in polyethylene or plastic bags to provide an additional barrier to fly breeding. Enough containers should be provided on all premises so that refuse need never be stored in boxes, cartons, bags, or simply left on the ground. Heavy plastic bags are widely used as liners for refuse containers, but should not be used as substitutes for garbage cans. Plastic bags can be torn open by cats, dogs, and rats and, as generally used, are often not fly-tight. Garbage cans should be kept on a neat and easily cleaned rack, platform, or slab (Figure 37). Spillage of garbage on soil can be a source of fly production and this should be avoided. Cans should be of 20 to 32 gallon capacity or smaller. Larger cans make the job of collection too difficult. At large apartments and business establishments, such as restaurants, large metal bulk containers are more satisfactory generally than garbage cans. They should have lids which close automatically and be so constructed that they can be cleaned easily. Fly larvae are often found in the sludge in the bottom of garbage cans and bulk containers. Ashes and other heavy refuse may be stored in cans of 20 gallon capacity or less. Householders should be familiar with local collection requirements. Most cities provide separate collections for household garbage and refuse and for trash such as leaves, metal, glass, brick, and junk wood. The public health worker has his greatest opportunity for community fly control through a program of better refuse storage, collection, and disposal.

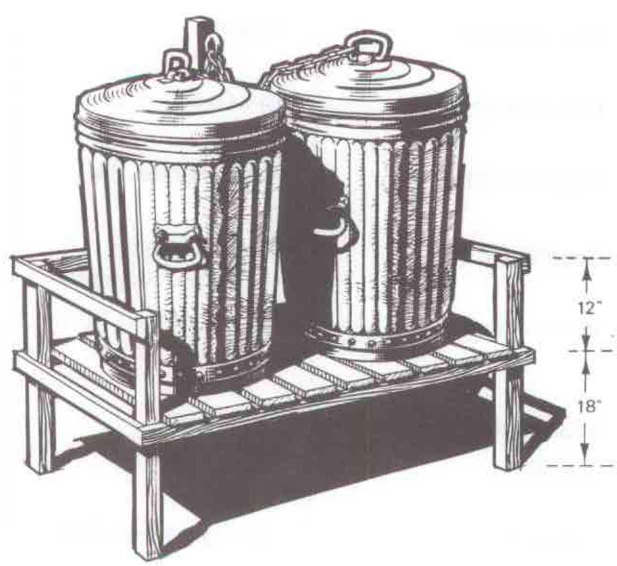


Figure 37. Approved Garbage Cans and Storage Rack

REFUSE COLLECTION

Under optimum summer temperatures, the eggs of domestic flies hatch in 12 to 24 hours, and the three larval stages are completed in 3 to 4 days. In order to prevent fly larvae in garbage cans and bulk containers from migrating out to pupate in the ground nearby, refuse should be collected from premises at regular intervals: twice weekly from residences and daily from businesses, particularly food-handling establishments, hotels, and large apartments. If flies do gain access to garbage, it will be removed and destroyed before a new generation of flies can reach the adult stage. Collection personnel should be neat, courteous, and efficient. They should take care not to spill refuse or damage garbage cans. Collection trucks should be of the packer type, or designed for pickup of bulk containers, and should have qualified operators. Trucks should be kept clean. Collection routes should be efficient and some system devised to ensure that no premises are missed. The collection system should be designed for the improvement of sanitation and not for the convenience of the collection agency.

REFUSE DISPOSAL

The Open Dump

This is an ancient but unsatisfactory method of refuse disposal which is still found near many villages, towns, and cities. A dump is a blight on the health of any community and should be replaced as rapidly as possible with a more sanitary disposal method. Many government agencies, such as the Environmental Protection Agency, are working to eliminate open dumps, with its much publicized "Mission 5000" whose objective is to eliminate 5000 open dumps (*63*). Littering, or the promiscuous dumping of refuse in vacant city lots, along country roads, in swampy places, and similar locations, results in a series of small open dumps throughout a community. These often contribute significantly to the fly problem.

The Sanitary Landfill

The sanitary landfill is one of the most economical and adaptable methods of disposing of garbage and refuse. At a properly operated sanitary landfill, the most important practice to reduce fly breeding is compacting the refuse and covering it with 6 inches or more of earth *daily* (*4*). When the landfill is completed, a final cover of 24 inches of compacted earth effectively eliminates fly, mosquito, and rodent breeding. There is no need for separate disposal of brush, concrete, or other rubbish as all these materials are placed in the fill. Low, swampy, submarginal land may be reclaimed as a byproduct, further reducing populations of mosquitoes and flies, and increasing property value (*7*).

Milling

Garbage, tin cans, bottles, cardboard, and small plastic containers (residential and light commercial refuse) are milled, or shredded, or pulverized by special milling equipment. The milled refuse is placed in the landfill site **without daily cover.** Amazingly, the milled refuse apparently is not acceptable food for rats and does not produce offensive odors or large numbers of flies under normal operating conditions. In their final report on the Milwaukee milling project, Reinhardt and Ham (*46*) reported that "there are several mechanisms

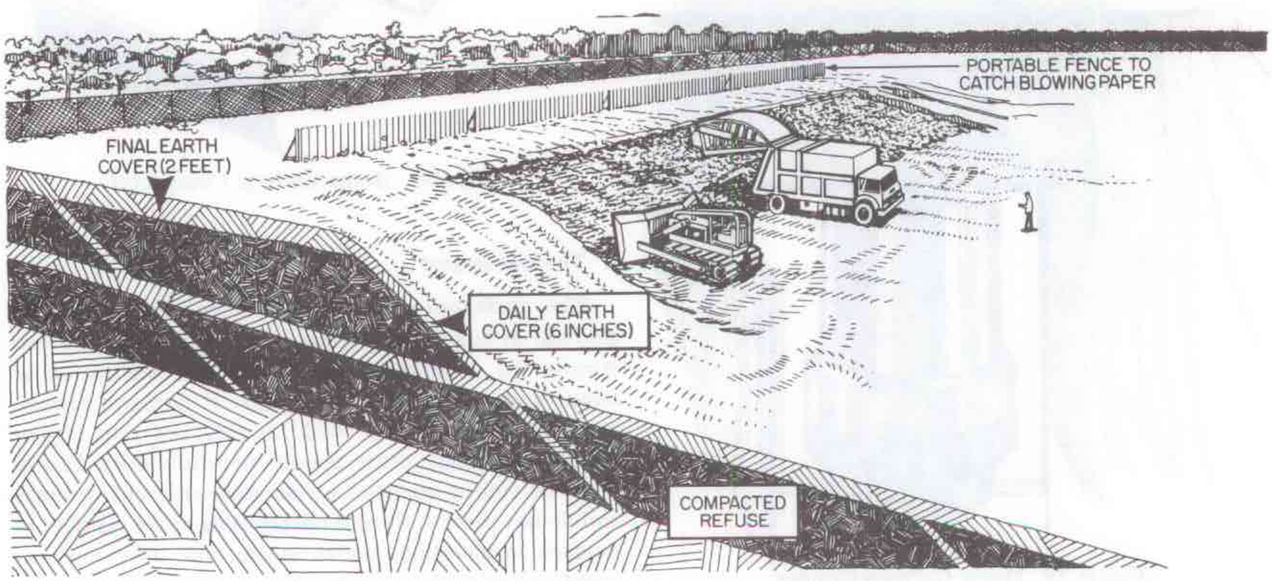


Figure 38. Sanitary Landfill

which would lead to reduced fly populations at landfills with milled refuse without cover. First, the milling process destroys the great majority of maggots. Second, freshly milled refuse can support the fly cycle only under optimal environmental conditions that are not normally found in a landfill. Finally, when refuse has aged for several months, even this ability under optimal conditions is destroyed." If flies or birds such as starlings or seagulls become problems at disposal sites with uncovered milled refuse, the addition of 6 inches of compacted earth at the end of each day's work, as at properly operated sanitary landfills, should solve these difficulties.

The Home Garbage Grinder

Electric garbage grinders provide sanitary disposal of garbage where sewer systems are adequate. These appliances (Figure 39) remove putrescible wastes in which fly production often occurs but still leave other rubbish such as cans, bottles, and cardboard boxes which must be collected regularly. In many communities local regulations require all new homes to have garbage grinders.

The Home Garbage Compactor

In recent years a number of home garbage compactors have been produced which can compress 20 to 30 pounds of garbage, a week's supply for most families. into a small treated bag. In a study at Atlanta, Georgia, with nearly 400 compactors installed in homes, many of the residents reported one of the important advantages was that they did not have to make a trip to the garbage can every day (*5*). The study indicated that the average compacted bag weighed about 20 pounds. The City of Atlanta reported considerable savings in the curbside pickup of a single small bag of compacted garbage once a week as compared with twice a week backyard or alley collection from conventional garbage cans.

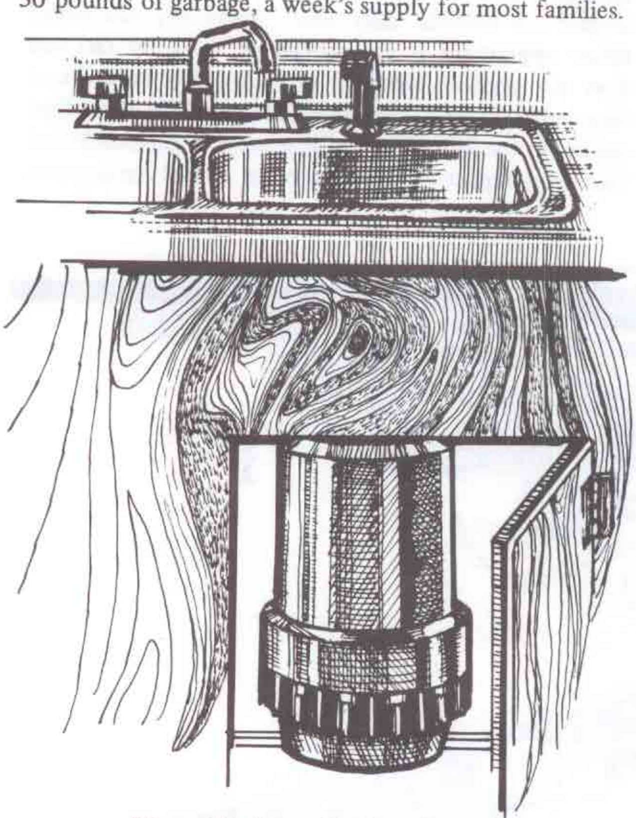


Figure 39. Home Garbage Grinder

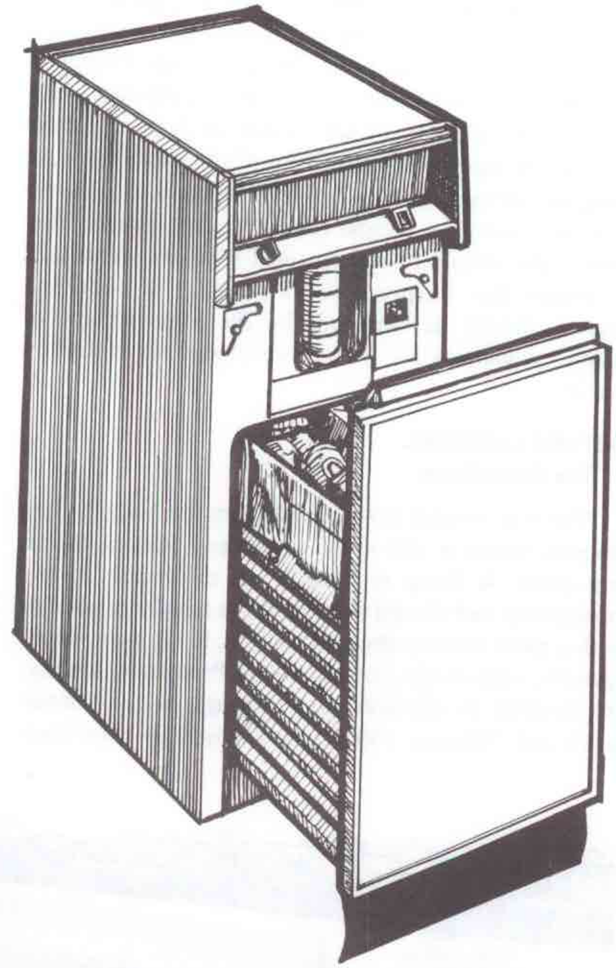


Figure 40. Home Garbage Compactor

The Incinerator

The incinerator is a practical method of refuse disposal in large cities where sites for landfills are too remote for economical use. Complete combustion at temperatures of 1,400° to 2,000° F destroys organic material that furnishes food for flies and rats. Higher temperatures may cause operational difficulties. Poorly designed and/or operated incinerators only char garbage and do not prevent fly and rat breeding in the residue. In modern incineration, metal, steam, and ashes are salvaged and sold, allowing the plant to operate at low cost.

SEWAGE AND INDUSTRIAL WASTE DISPOSAL

Sanitary disposal of sewage and industrial waste is of greatest importance in any fly control program. The open privy produces large numbers of flies, and each filth-laden fly is a menace to human health. The sanitary pit privy with closed pit and housed seat is a vast improvement, but even this is dangerous to health and should be replaced as soon as possible by modern and efficient disposal facilities. The properly constructed septic tank is a temporary solution to this problem in rural and newly developed areas, but cities and towns should provide sanitary sewers and a complete sewage treatment plant. Exposed wastes are too dangerous to human health to be tolerated.

Food canneries, feed mills, abattoirs, and packing houses produce large quantities of organic wastes that require proper storage and disposal. These wastes are often the most prolific fly-breeding sources in a community. Some of the more important wastes are spilled feed, blood, urine, paunch contents, melon rinds, and pea hulls. Breeding often becomes so great under these conditions that vast hordes of flies will move out into surrounding areas seeking less crowded breeding sites.

Each type of industrial plant has special waste problems that must be solved if effective fly control is to be achieved. Large plants can often use wastes to produce valuable byproducts, such as fertilizer or salvaged fats. Smaller plants must resort to other means, such as the sanitary landfill, for waste disposal. Storage in closed containers for a minimum time plus adequate disposal, will go a long way toward eliminating the problems. The paving of waste storage areas will prevent organic matter from soaking into the soil and causing objectionable odors and fly breeding. Concrete platforms with suitable drains can be maintained in a sanitary condition with a minimum of labor. Areas where waste is stored should be cleaned daily.

ANIMAL FEEDS, EXCREMENT, AND OTHER MINOR BREEDING SOURCES

Minor breeding sources may play a greater or lesser role in the domestic fly problem. A concerted effort should be made to locate and eliminate as many of these as possible. Look for such things as animal feeds which are kept wet by rainfall, accumulations of animal manures improperly spread or poorly stored, and for dog stools (Figure 41), chicken manure, and other animal excrement not usually surveyed. In short, search out and eliminate any accumulation of organic material which remains moist long enough to produce flies.

Figure 41. Animal Waste Control

In many communities the fly problem is associated with caged chicken farms. Heavy fly breeding can be prevented by periodic removal of the chicken manure and disposing of it by (1) using it as fertilizer and spreading it thinly (1/8 to 1/4 inch) so that it will dry quickly, (2) combining a water carried manure removal system with a properly operated sewage lagoon, (3) composting, (4) stockpiling it under heavy plastic tarpaulins, or (5) disposing of it in a sanitary landfill.

WEEDS

Weeds are an open invitation for large populations of flies. They provide extensive and varied cover for the pests, make insecticide application difficult, and prevent adequate control of refuse, feces, and other breeding media. Herbicides such as 2, 4-D give good control of broad-leaved plants, while others are specific for undesirable grasses. Mowers and clippers can be used when herbicides might endanger valuable plant life.

ENVIRONMENTAL CONTROL OF NONDOMESTIC FLIES

Elimination or alteration of larval habitats may help control some of the nondomestic flies of public health importance. General suggestions for control are shown in Table 5.

TABLE 5. METHODS OF ENVIRONMENTAL CONTROL OF NONDOMESTIC FLIES

Scientific Family Name	Method of Environmental Control
Ceratopogonidae	Diking salt marshes for some species of *Culicoides* (*33*).
Chironomidae	Draining of standing water.
Chloropidae	Reducing accumulations of organic waste.
Hippoboscidae	Keeping healthy animals away from those that are infested.
Piophilidae	Keeping infested and noninfested foods separated; rewrapping improperly protected hams and cheeses.
Psychodidae	For filter flies, cleaning plumbing of gelatinous material, eliminating accumulations of stagnant water. For sand flies, eliminating rock piles and debris.
Simuliidae	Modify flow of streams where larvae live; in some dam outlets, providing two spillways, so the water course can be alternately flooded and completely drained.
Tabanidae	Draining damp areas may help with some species.

DOMESTIC FLY CONTROL WITH INSECTICIDES

Effective fly control depends primarily on the integrated control approach: proper storage, collection, and disposal of refuse to prevent fly breeding; screens; release of fly parasites and predators; and judicious use of insecticides to kill problem species. Chemical control procedures include residual sprays, fly baits, impregnated cords, space sprays, and larvicides. While each measure by itself may be effective to a certain extent, it is frequently desirable to use two or more methods at the proper time to achieve maximum control. For example, flies at a garbage storage area, a dairy barn, or a chicken ranch may be more effectively controlled by a combination of residual sprays and baits than by either method alone. In many areas, house flies have developed resistance to the chlorinated hydrocarbon and organophosphate insecticides but the lesser house flies, blow flies, and stable flies are still susceptible to many organic insecticides. Therefore, the correct identification of the problem flies and a knowledge of their susceptibility to insecticides are essential to the success of any control program.

THE DECISION TO APPLY ANY INSECTICIDE IS THE RESPONSIBILITY OF THE AGENCY OR INDIVIDUAL CONCERNED. EACH PERSON APPLYING AN INSECTICIDE SHOULD BE CERTAIN THAT THE INTENDED USE IS IN CONFORMANCE WITH EXISTING LOCAL, STATE, AND FEDERAL REGULATIONS AND WITH THE LABEL INFORMATION. The following general recommendations are based on information published by the Center for Disease Control (*9, 10*), U.S. Navy (*65*), and the World Health Organization (*71*).

RESIDUAL SPRAYS

For many years residual sprays were one of the major methods of controlling house flies. However, the house fly has developed resistance to many of the chlorinated hydrocarbon and organophosphate insecticides and these treatments are of little value in controlling this species although they are effective against other species such as the little house flies and blow flies. Table 6 indicates that the following insecticides may be used as residual sprays indoors: dimethoate (1%), malathion (3%), and ronnel (1%). For outdoor application the addition of sugar helps to prolong maximum effectiveness. One percent propoxur may be used outdoors. Depending on the level of sanitation and the intensity of fly breeding, such residual spray treatments may have to be repeated as often as every 2 to 4 weeks (*10, 45*).

FLY BAITS

Flies can be controlled by dry or liquid baits containing diazinon, dichlorvos, dimethoate, malathion, naled, ronnel, or trichlorfon alone or in combination. Dry baits contain 1 to 2% of the insecticide and an attractant such as sugar, coated over an inert carrier such as ground corncob, oyster shell, or sand. Liquid baits contain 0.1 to 0.2% of the insecticide and 10% sugar as an attractant dissolved in water. Commercial baits containing these insecticides are available, or the baits can be prepared from water-wettable powders or emulsifiable concentrates. Dry baits scattered by hand or from a sifter-type container produce dramatic reductions in fly populations within a few hours but are effective for only a day or two, particularly if placed on damp dirt surfaces. Permanent bait stations reduce the time and effort required to provide constant insecticidal pressure on the fly populations. These bait stations include simple plywood trays covered with hardware cloth for dry baits (Figure 42) and chicken-watering fountains with a cellulose sponge in the trough to prevent clogging with dead flies (Figure 43) for liquid baits. If the emulsifiable concentrate of the organophosphate insecticide is not readily available, a piece of dichlorvos resin strip may be placed in the sugar water in the chicken-watering device. These are sometimes used

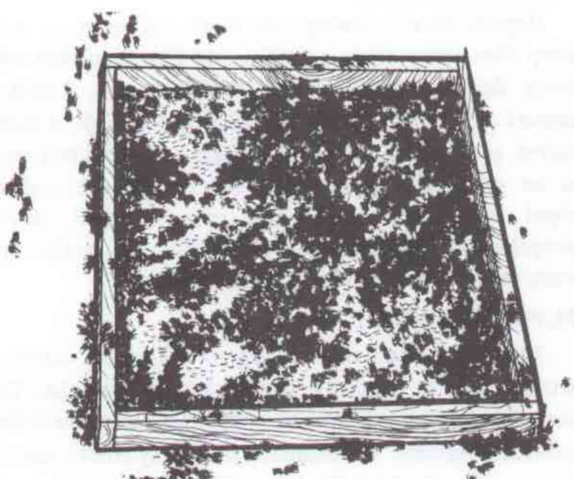


Figure 42. Tray for Dry Fly Bait

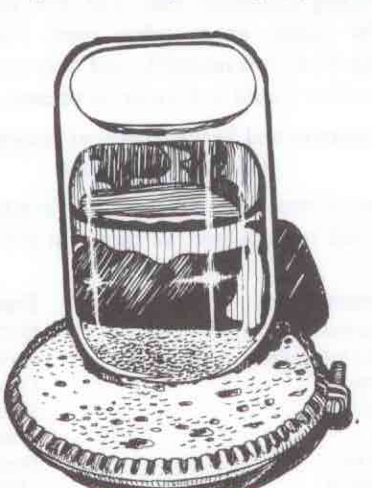


Figure 43. Chicken Watering Fountain for Liquid Fly Bait

to provide fly control in backyards near barbecue grills. People using fly baits should check regulations before applying them. Most of them can be used in dairy barns and chicken houses, but trichlorfon is not registered for use in poultry houses. Data from studies in Georgia and Florida indicate that flies resistant to residual sprays were killed by baits containing these same organophosphate insecticides (*10, 65*).

SPACE SPRAYS

Space sprays are based on the concept of actually hitting the insects with a lethal particle of the insecticide. They do not provide a residual deposit of the toxicant and must be repeated periodically, sometimes before each meal in food-handling establishments, or each day in dairy barns.

For indoor use householders frequently rely on hand-operated sprayers, or aerosol dispensers (Figure 44) containing 0.1-0.2% of synergized pyrethrin or allethrin for quick knockdown of pest flies. In food-handling establishments automatic aerosol dispensers which release a measured amount of pyrethrins or allethrin at regular intervals, such as every 15 minutes, have been widely used in recent years. Dairy and beef cattle farmers frequently use electric mist sprayers to apply deodorized kerosene solutions of synergized pyrethrin or allethrin (0.1%), malathion (2%), or ronnel (2%) inside barns (*10*).

For outdoor use, space sprays have been used effectively at refuse dumps, near slaughter houses and cattle feed lots, and in alleys near foodhandling establishments and cargo storage areas. "In field tests in

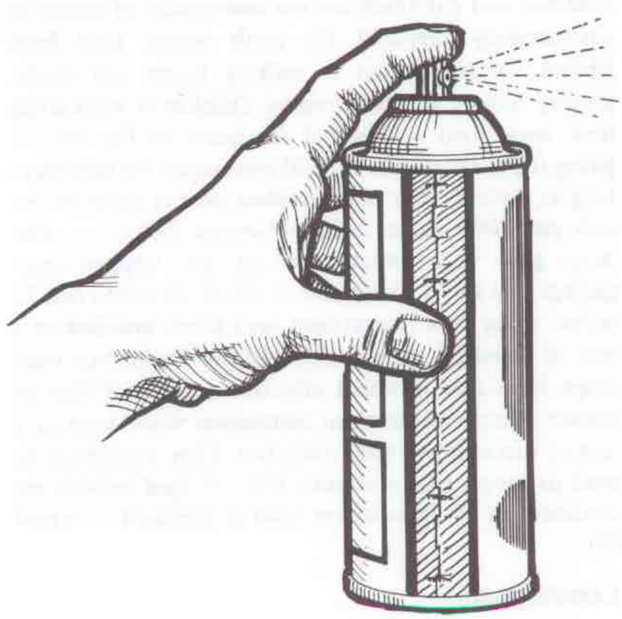


Figure 44. Aerosol Dispenser

Georgia, the pound-per-acre dosages required for effective kills at distances up to 200 feet for six compounds were malathion (0.6); ronnel (0.4); fenthion (0.4); dichlorvos (0.3), naled (0.1 to 0.2) and dimethoate 0.1 to 0.2." In limited field-tests at a poultry ranch in Georgia, ground applications with a backpack mist blower of resmethrin as low as 0.025 lb. per acre gave effective control of house fly populations within 2 hours (*10*).

Good control of stable flies in wooded areas over a half mile wide along west Florida beaches was obtained using 25% naled dissolved in soybean oil. The material was applied at a rate of 1.3 fluid ounces per acre from airplanes flying in four swaths 200 feet apart parallel to the treated area. Similar tests with 40% resmethrin by volume in soybean oil applied at a rate of 1.7 fluid ounces per acre gave more than 90% control of stable flies at an average distance of 1,400 feet downwind. These control experiments were done under research conditions and did not have EPA label permission in April 1974 (*47*).

FLY CORDS AND RESIN STRIPS

The installation of insecticide-impregnated cotton cords at a rate of 30 linear feet of cord per 100 square feet of floor space has provided good fly control in dairies, chicken ranches, and "pig parlors" for periods varying from 6 weeks to an entire season. The flies rest on the cords and absorb a lethal dose of insecticide through their feet. CDC research has shown that better fly control occurs when the cords are hung vertically (as 15 pieces of cord 2 feet long, or 10 pieces of cord 3 feet long, per 100 square feet of floor space) rather than horizontally (as 30 feet of cord parallel to the floor). Diazinon and parathion are the insecticides of choice in commercially prepared fly cords which have been labeled for installation in milking barns, calf sheds, poultry houses and feed rooms. Dichlorvos resin strips have been used as residual fumigants in fly control, giving off a lethal dose of dichlorvos vapor for periods as long as three to four months when used at a rate of one unit per 1000 cubic feet. In Georgia dichlorvos resin strips gave 95% reduction of all flies trapped from garbage pits (with a diameter of about 30 inches and 72 inches deep) in a recreational area when installed at a rate of one-half to one unit per pit. Dichlorvos resin strips have also provided effective control of flies in indoor areas with minimal ventilation when used at a rate of one unit per 1000 cubic feet. They should not be used in rooms where infants, sick, or aged persons are confined, or in areas where food is prepared or served (*9*).

LARVICIDING

Larviciding for the control of domestic flies has never been very successful. One of the real problems is adequate penetration of the breeding media (as garbage or manure) so that the chemical actually comes in contact with the larvae. However, new developments such as the use of juvenile hormone type chemicals may make this type of control more productive. Some workers have attempted to alter the chemical makeup of the breeding media so that, although the females lay eggs in it, the larvae do not reach maturity. The traditional example is the addition of borax to manure to retard fly breeding. Such treatment makes the manure unsuitable as fertilizer. Chloride of lime, used to deodorize privies, is a poor larvicide. Some chemicals which have shown promise as larvicides are diazinon (0.5% to 1%), dimethoate (1.0% to 1.25%), and dichlorvos (0.5% to 1.0%). In garbage cans the addition of two ounces of paradichlorobenzene every week or two is effective. Small pieces of dichlorvos resin strip placed in special holders in garbage cans have given good control of domestic flies for two to three months or longer.

FLY REPELLENTS

Repellents are coming into more and more use to (1) keep flies away from animals, and (2) keep flies away from doors of food service establishments. Livestock smears and sprays commonly used contain oil of cloves, safrol, pine oil, camphor, or tabutrex. Diethyl toluamide is an excellent fly repellent for human use and will repel mosquitoes, ticks and mites as well. Several proprietary materials are available for use as fly repellents around food service establishments (*17*).

FLY ATTRACTANTS

Attractants have been used to a limited extent to attract flies to specially treated breeding media. This, however, has been found to have little use in most large control programs. The addition of new synthetic lures to dry organophosphate fly baits offers promise of success in controlling domestic flies and eye gnats (*38, 39*). Sticky fly paper, once widely used, has fallen into general disuse as it is unsightly and only serves to attract more flies than would ordinarily be present.

Common and Trade Names of Insecticides Used in Fly Control

A number of insecticides listed in Table 6 have different common and trade names, as shown in the two columns below:

Common Name	Trade Name
dichlorvos	DDVP, Vapona
diethyl toluamide	DEET, OFF
dimethoate	Cygon
fenthion	Entex
naled	Dibrom
propoxur	Baygon
resmethrin	SBP-1382
rabon	Gardona
ronnel	Korlan
trichlorfon	Dipterex

TABLE 6. SUGGESTED INSECTICIDES FOR FLY CONTROL

(These suggestions are guidelines only. User must ensure that the insecticide is applied in strict compliance with the label and with local, state and federal regulations).

TYPE OF APPLICATION	INSECTICIDE AND FORMULATION*	REMARKS*
Aerosol	allethrin or pyrethrin 0.1-0.2% plus synergist. dichlorvos 0.5%	Make spot treatment for small numbers of flies inside building. Apply 10-15 seconds per 1000 cubic ft.
Space Spray Indoors	pyrethrins 3-5% OS	ULV treatment can be made only when area is unoccupied. Put out all flames, open all cabinets, and drawers. Remove, refrigerate, or cover all food. Apply at rate of 1/2 oz./1000 cubic feet. Minimum exposure time is one hour. Ventilate well before re-entry. Wash down food preparation surfaces before use.
Residual Spray Indoors	dimethoate 1% E malathion 3% E ronnel 0.5-1% WP Rabon 1-2% WP	Spray walls, ceilings, and other surfaces to obtain complete coverage. Avoid contamination of food, foodstuffs, and water.
Wet Bait Outdoors	dichlorvos 0.1% B malathion 0.1-0.2% B	Apply 1-3 gals./1000 sq. feet as sugar-water bait where flies congregate, not on dirt or litter. Use chicken-watering fountain.
Dry Bait Outdoors	dichlorvos 0.5-1.0% malathion 1-2% B dimethoate 1-2% B trichlorfon 1-2% B ronnel 1-2% B	Apply with shaker to fly-infested areas at 3-4 oz./1000 sq. feet. Place in permanent bait station trays covered with hardware cloth.
ULV and Thermal Treatment Outdoors	pyrethrins 5% + 25% piperonyl butoxide in oil ULV	Use 0.002-0.0025 lb./acre.
	resmethrin 40% SBP 1382 MF, OS	Apply at 3 oz./acre or 0.007 lb. toxicant per acre.
Mist Treatment Outdoors	fenthion dichlorvos malathion naled	11 gal. 25% EC in 34 gal. water 6 gal. 50% EC in 44 gal. water 5 gal. 55% EC in 41 gal. water 1.5 gal. 65% EC in 50 gal. water. Apply at 15-20 gal. per mile. Do not contaminate water or feed, allow no mist on people or animals.
Residual Spray Outdoors	propoxur 1% E, WP, OS	Apply to screens, doors, window frames and other surfaces where flies congregate. Do not use on vegetation.
Larvicide Residual Spray	dimethoate 1-1:25% E dichlorvos 0.5%-1% E malathion 0.5% E	Apply at 7-14 gal./1000 sq. feet as coarse spray. Avoid contamination of feed and water, or spraying chickens or livestock.

TABLE 6 (CONTINUED)

TYPE OF APPLICATION	INSECTICIDE AND FORMULATION*	REMARKS*
Larvicide Fumigant	paradichlorobenzene 100% crystals	2 oz./garbage can every 1-2 weeks.
Larvicide Fumigant	dichlorvos resinstrip	1 piece per garbage can in special holder, every 3-4 months.
Repellent	diethyl toluamide (DEET, OFF)	Apply to skin or clothing as required. Repeated applications may result in blisters at bend of knee and elbow. Keep out of eyes. May injure plastic.

Symbols in second and third columns show: A=aerosol; B=bait; E=emulsion; EC=emulsifiable concentrate; F=fumigant; M=mist; OS=oil solution; WP=wettable powder; ULV=Ultra Low Volume.

Since the passage of the Federal Environmental Pesticide Control Act of 1972, many of the state agricultural experiment stations or the state extension services have printed handbooks with recommendations about insecticidal control. For information regarding safe insecticides for any purpose in your state, consult these up-to-date references.

RESISTANCE TO PESTICIDES

Resistance is the ability of insect populations to withstand a concentration of an insecticide which was generally lethal to earlier populations. Resistance is a reflection of overpopulation acted upon by natural selection to produce survival of the fittest. More individuals are born than can survive. Populations are highly variable and the individuals that are most resistant to insecticides stand the best chance of surviving and reproducing. New generations will then consist primarily of descendants of increasingly resistant parents. Insecticides modify conditions under which insect populations must exist. Individuals that are able to withstand the insecticide survive to rebuild the population. Two main types of resistance have been detected: physiological and behavioristic (*6, 56*).

PHYSIOLOGICAL RESISTANCE is a complex phenomenon which may involve:

Differential Absorption Rate Contact insecticides must penetrate the exoskeleton of insects in sufficient quantities to kill. Some individuals in the insect population have slower absorption rates than others. During the routine chemical applications, individuals with slow absorption rates receive sublethal doses.

Storage Some individuals in the insect population are able to store the insecticide in a physiologically non-sensitive tissue such as the fat body before it can kill.

Excretion Some members of the insect population are able to excrete the insecticide before it can kill.

Detoxification Certain individuals in an insect population are able to detoxify the insecticide before it can kill. This detoxification is usually brought about by enzymatic action. Detoxification products may be stored, excreted, or metabolized.

Alternate Accomplishment of Blocked Functions Insecticides kill by interfering with the biochemical balance of the insect. Some individuals can regain normal activity by substituting another biochemical system for the one damaged by the chemical (*56*).

BEHAVIORISTIC RESISTANCE involves the reaction of flies to insecticides with regard to:

Habitat Some flies occupy a habitat different from that of the vast majority. During routine insecticide applications, the normal-habitat majority is killed while the "out-of-the-way" minority survives and reproduces.

Avoidance Some individuals in an insect population are sensitive to the insecticide and tend to avoid it. During routine control operations, some flies avoid, perhaps are repelled by, insecticide-treated surfaces, fly cords, or fly baits. Some sensitive individuals survive and reproduce.

TOLERANCE results when members of an insect population receive sublethal doses of an insecticide, and some physiological reaction occurs which protects these insects from later applications of the same chemical. This protection is not passed on to the next generation. Minute quantities of highly stable insecticides, such as DDT, may remain in the environment for many years, thereby perpetuating acquired physiological resistance.

Not all reports of resistance are valid. Other possibilities should be explored. For example, did the spray crew actually apply the insecticide as instructed? Was the proper insecticide used in the proper manner and at the proper concentration? Was the batch of insecticide faulty? Did a new population move into the area? Did the old population rebuild itself so rapidly that reduction was not apparent?

Brown and Pal (*6*) report at least 21 species of flies of public health importance were resistant to one or more insecticides by 1970. The list includes some of the most important species such as the house fly, lesser house fly, stable fly, green bottle fly, a biting midge (*Culicoides)*, an eye gnat, a filter fly, and several species of midges.

TABLE 7. SUGGESTED CHEMICAL CONTROL OF NONDOMESTIC FLIES

Scientific Family Name	Method of Chemical Control
Ceratopogonidae	Apply diethyl toluamide to individuals affected.
Chironomidae	Use juvenile hormone type chemicals in aquatic breeding places if legally permitted (*40*).
Chloropidae	Use attractant bait insecticide combinations (*39*).
Hippoboscidae	Dust infested animals with 0.2% synergized pyrethrins or 5% carbaryl dust.
Piophilidae	Space spray with 0.1% synergized pyrethrins.
Psychodidae	Residual spray with 5% malathion suspension: all living quarters for adult *Phlebotomus* and *Lutzomyia;* walls and resting places for *Psychoda* adults near sewage treatment plants.
Simuliidae	Apply diethyl toluamide to repel adult black flies. Apply Abate or methoxychlor to stream breeding places of larvae and pupae if legally permitted (*25, 26*).
Tabanidae	Space spray for temporary relief with malathion, dichlorvos, pyrethrins, resmethrin when legally permitted.

MECHANICAL AND PHYSICAL CONTROL OF DOMESTIC FLIES

SCREENING

Screening buildings is the most widely used fly exclusion technique. Although costly, and not detrimental to the fly populations, this method can keep buildings virtually free of flies and will therefore be continued as long as major insect problems remain unsolved. Screens should be made of copper, aluminum, plastic or some other noncorrodible material. They should be mounted on durable frames and should not detract from the appearance of the building. The size of screen should be about 16-mesh (16 strands to the inch) in order to give the greatest protection without undue loss of light or air circulation. The screens should fit tightly in the window or door frames so that the flies and other insects cannot enter around the edges. In most situations it is not necessary to screen windows above the fourth story in tall buildings to exclude flies (*44*).

FLY TRAPS

While useful for survey purposes, traps merely harvest the excess fly population and give little immediate relief, and no long range control. New research with fly

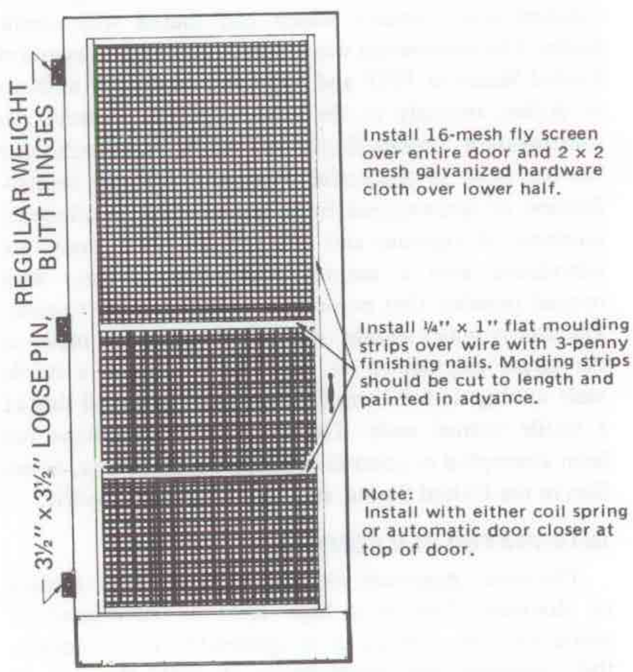


Figure 45. Flyproof Screen Door

attractants may add to the usefulness of fly traps in the future (*38, 39*).

ELECTROCUTION

Electrocution has proven effective under certain situations. Two common techniques are used. In the first, a fly trap is electrified. In the second, electrification of window and door screens is accomplished using house current transformed to low amperage and high voltage (3,500 to 4,000 volts is desirable). When the flies alight on the screens, they are immediately killed, yet these screens will not harm a human being or other large animal. Installation of electric screen is very expensive. It has been used where the fly problem is acute, as at some dairies, paper mills, and milk processing plants.

ELECTRIC FANS

Fans mounted over doorways leading to food service establishments will keep out a significant percentage of flies. Large buildings sometimes have air barriers or doors, to keep out dust, smoke, and insects, but which are hardly noticeable to persons passing in and out. In a careful study on the use of air fans, Mathis, Smith, and Schoof (*36*) showed that "air velocities greater than 1500 feet per minute at the 3-foot level are required to obtain any reasonable degree of efficiency (i.e., 80% or above). . .Public acceptance of such velocities at food-handling establishments is questionable. . .With a low fly density, an 80% protective barrier might be highly satisfactory, whereas the same level of efficiency with a high density would permit too many flies to enter a restaurant."

BIOLOGICAL CONTROL OF DOMESTIC FLIES

RELEASE OF STERILE FLIES

The classic example of the sterile male technique to control or eradicate insects is the program which eradicated the primary screwworm (*Cochliomyia hominivorax*) from the southeastern United States (*30*). Millions of screwworms were reared in the laboratory. Males were irradiated with radioactive cobalt and liberated in the field where they mated with normal females. Since the female screwworm mates only once, eggs never hatched from females which had mated with sterile males. The screwworm was eradicated from southeastern United States in 1958 and 1959 with savings of millions of dollars annually to the cattle industry. However, in southwestern United States the sterile male technique has not been so successful because of constant reintroduction of screwworms from Mexico (*15*). If adequate numbers of vigorous and competitive sterile males are introduced into a natural population to mate with normal females, that population will soon cease to exist. The sterile males should outnumber the fertile males in the target population so that the chances of a sterile male mating with a normal female greatly exceed that of a fertile normal male. The sterile male technique has been attempted in controlling tsetse flies in Africa, house flies in the United States, and fruit flies in the Pacific.

INTEGRATED FLY CONTROL

The most important element in satisfactory control of domestic flies is a high level of environmental sanitation. The concept of integrated fly control accepts this principle and supplements it with the use of biological agents and the judicious use of insecticides. Many parasites and predators decrease domestic fly production. Some bacteria, such as *Bacillus thuringiensis,* have been used. The protozoon, *Octosporea muscaedomesticae,* may be an important factor in controlling the house fly and several other domestic flies. Some species of mites, such as *Macrocheles muscaedomesticae,* prey upon flies. The larvae of a number of domestic flies such as *Ophyra* and *Muscina* feed on other species of fly larvae and have been reported to play a role in controlling house flies (*8, 9, 10*). A considerable number of tiny hymenopterous parasites have been reared from eggs and pupae of flies, particularly *Spalangia, Muscidifurax,* and *Tachinaephagus.* All of these parasites and predators are normal inhabitants of manure. In order to derive maximum benefits from biological fly control, these parasites and predators must be permitted to live in the dung. In chicken houses with caged layer-hens, it has been suggested that removal of the dung under alternate rows of cages would maintain large populations of these fly enemies which would migrate to new cones of chicken manure as the poultry rebuild them. On farms where chickens roam throughout the chicken houses, at the time of periodic (usually annual) cleanups, small piles of manure should be left as "seed" for future populations of these parasites and predators. Careful research indicates that an integrated control program of poultry manure management and residual spraying at 2- to 5-week intervals provided about as good control, with far less expenditure of labor and insecticides, as that resulting from weekly larviciding which destroyed the predator and parasite populations in the manure (*10*).

ORGANIZED FLY CONTROL

Effective fly control benefits the entire community. It can best be accomplished with an organized program, using all effective means. Since most fly control requires the cooperation of the entire community, education is the number one requirement of a good program. It begins with a realization of the problem by responsible individuals, extends through the orientation of public officials, and reaches its fruition in the education of all people in the community. Fly surveys, to determine the extent of the problem and to guide the control operations, must be made. Then, efficient and effective control measures must be taken. Additional surveys are used to evaluate the results of the effort and point out where more control measures are necessary (*67*).

Once a high degree of fly abatement has been achieved, a continuing program is necessary to maintain the gain. Yet, it is in this area that fly control programs most often fail. When flies are no longer a serious problem, public interest lags, other problems take away the attention of public officials, and the flies begin a gradual but certain reoccupation. Organized fly control should be incorporated into the regular program of every health department (*24, 32*).

SELECTED REFERENCES

Note: At the Federal level the ultimate source of recommendations for insecticides used in the control of flies is the "EPA Compendium of Registered Pesticides" (13).

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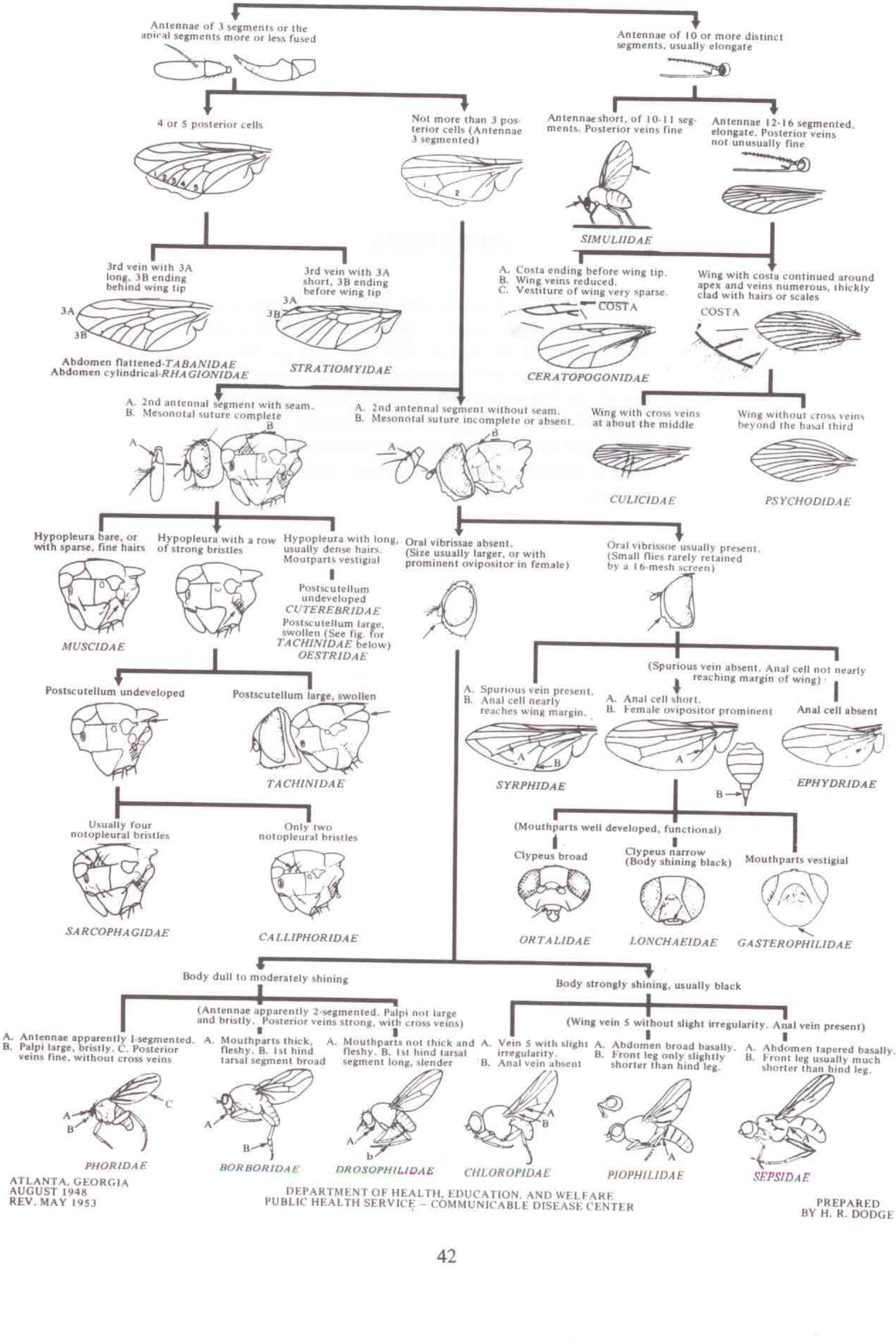
APPENDIX

The pictorial keys in this manual are typical of identification keys found in reference works and scientific papers. At the top of each key there are two or more statements with accompanying illustrations. Only one of the statements will apply to the specimen being identified. After making the proper choice, follow the black lines to additional choices. Continue this process until a definite answer (and correct identification) is reached.

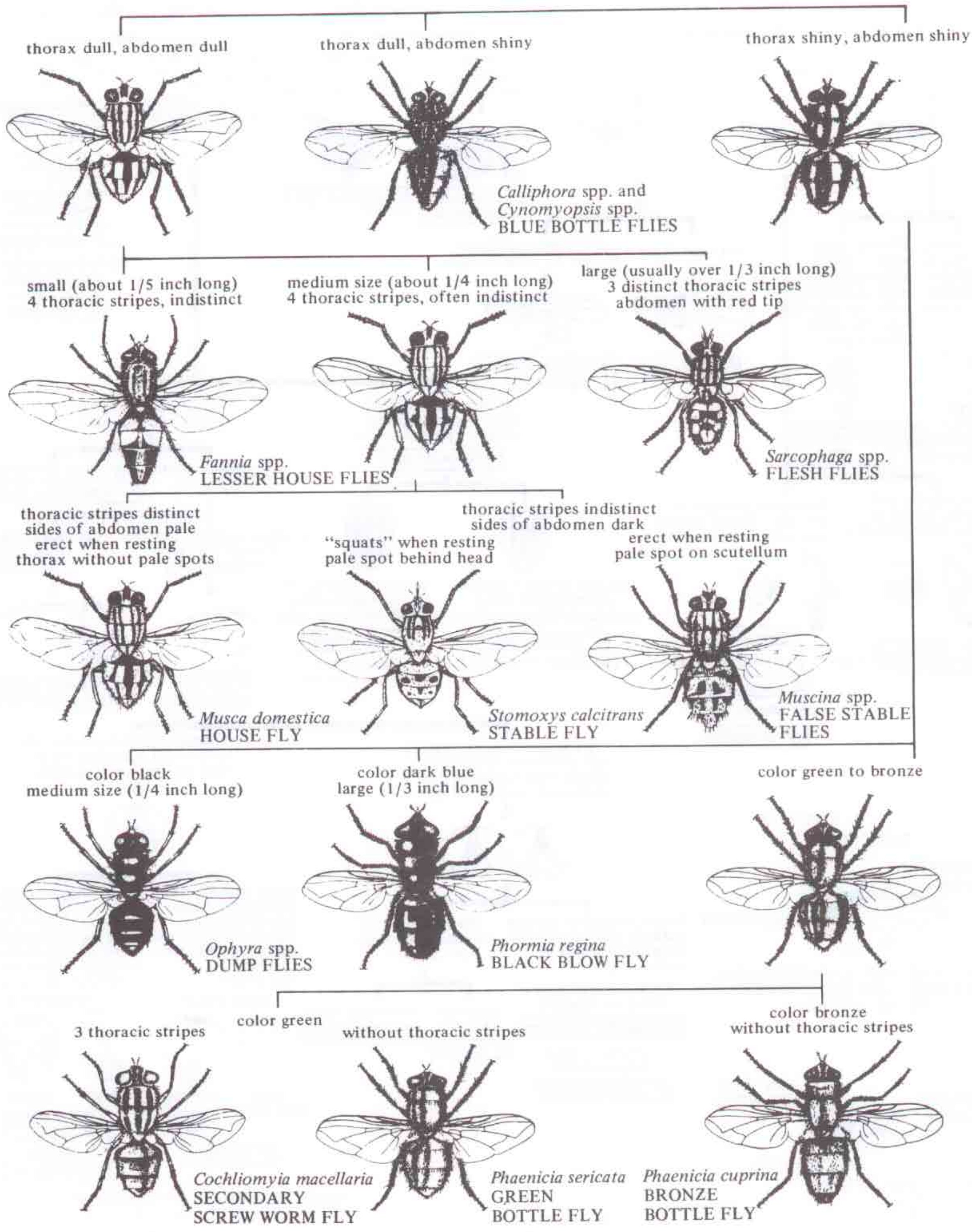
PICTORIAL KEY TO PRINCIPAL FAMILIES OF DIPTERA OF PUBLIC HEALTH IMPORTANCE



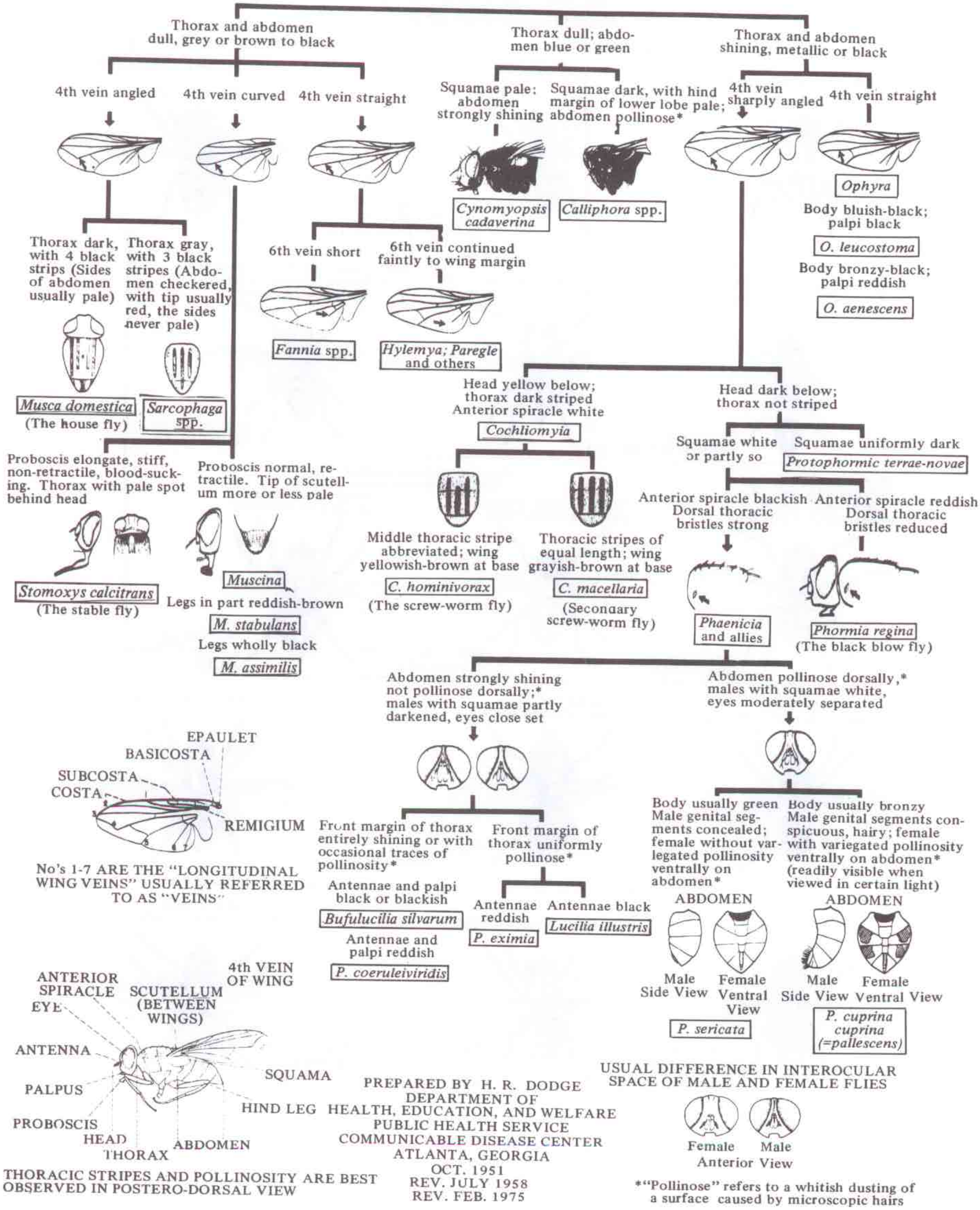
PICTORIAL KEY TO COMMON DOMESTIC FLIES

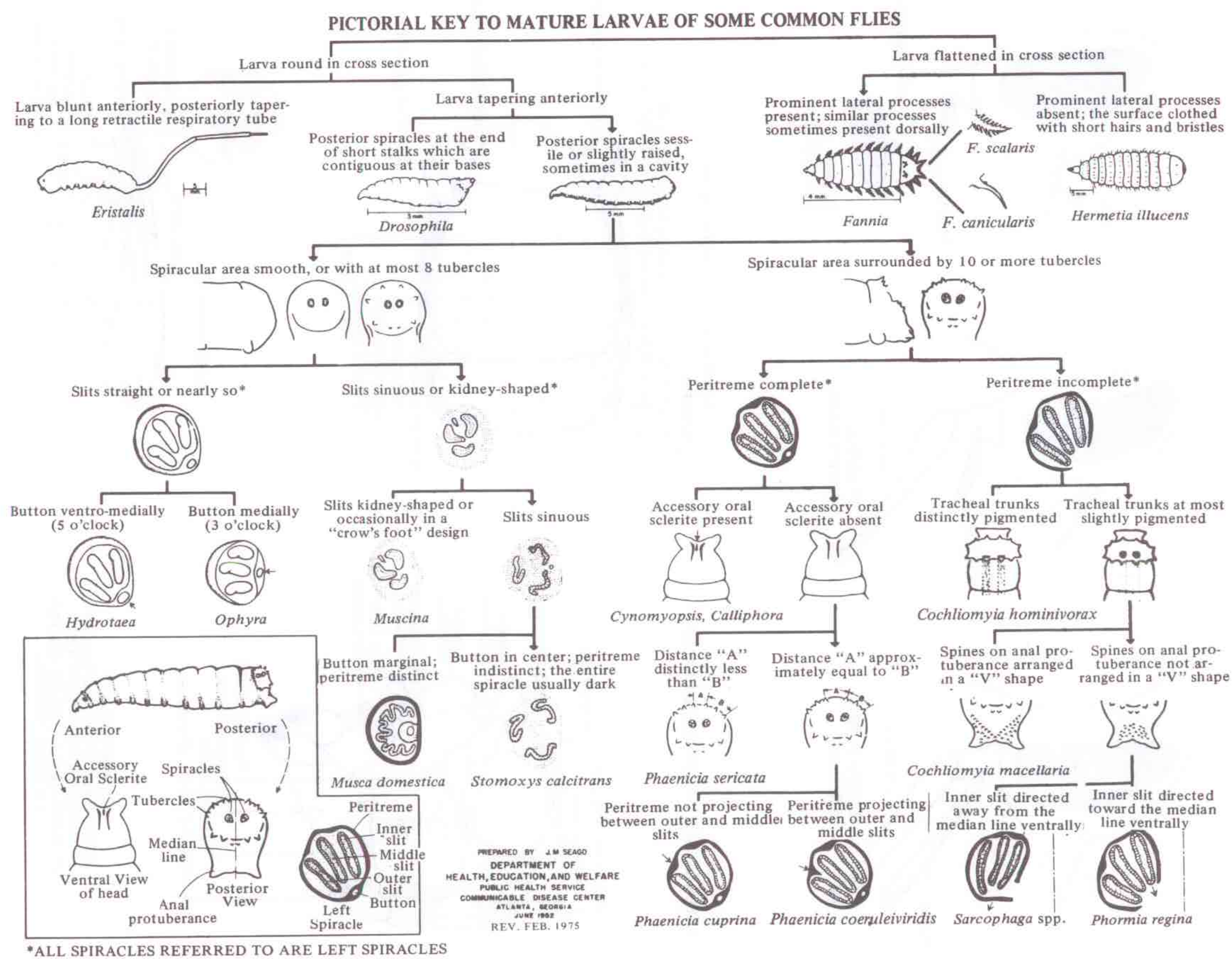
(for use with CDC fly grill record)

Harold Georgia Scott, Ph.D.

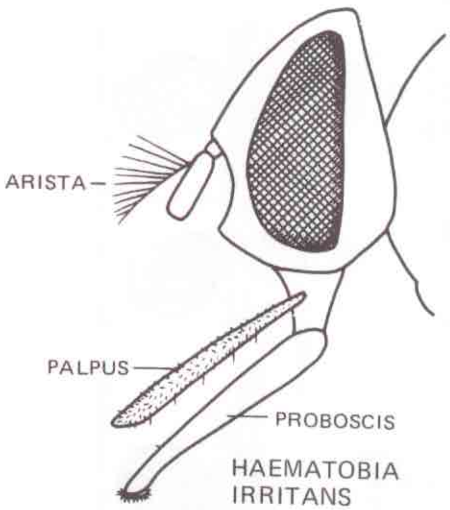


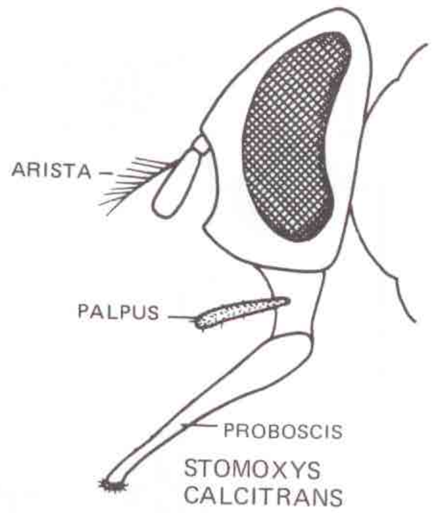
PICTORIAL KEY TO COMMON DOMESTIC FLIES IN THE U.S.

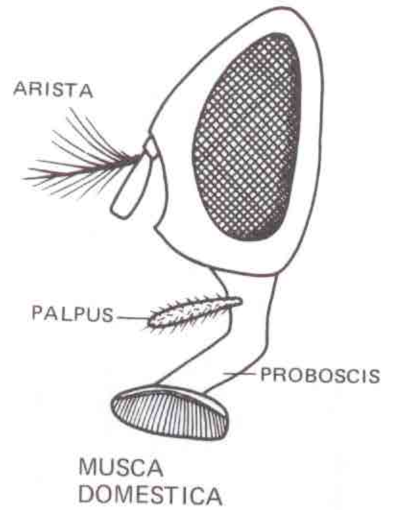



PICTORIAL KEY TO MATURE LARVAE OF SOME COMMON FLIES
Larva round in cross section
Larva flattened in cross section
Larva blunt anteriorly, posteriorly tapering to a long retractile respiratory tube
Eristalis
Larva tapering anteriorly
Posterior spiracles at the end of short stalks which are contiguous at their bases
Drosophila
Posterior spiracles sessile or slightly raised, sometimes in a cavity
Prominent lateral processes present; similar processes sometimes present dorsally
F. scalaris
Fannia
F. canicularis
Prominent lateral processes absent; the surface clothed with short hairs and bristles
Hermetia illucens
Spiracular area smooth, or with at most 8 tubercles
Spiracular area surrounded by 10 or more tubercles
Slits straight or nearly so*
Slits sinuous or kidney-shaped*
Peritreme complete*
Peritreme incomplete*
Button ventro-medially (5 o'clock)
Button medially (3 o'clock)
Hydrotaea
Ophyra
Slits kidney-shaped or occasionally in a "crow's foot" design
Slits sinuous
Muscina
Button marginal; peritreme distinct
Musca domestica
Button in center; peritreme indistinct; the entire spiracle usually dark
Stomoxys calcitrans
Accessory oral sclerite present
Accessory oral sclerite absent
Cynomyopsis, Calliphora
Distance "A" distinctly less than "B"
Phaenicia sericata
Distance "A" approximately equal to "B"
Peritreme not projecting between outer and middle slits
Phaenicia cuprina
Peritreme projecting between outer and middle slits
Phaenicia coeruleiviridis
Tracheal trunks distinctly pigmented
Cochliomyia hominivorax
Tracheal trunks at most slightly pigmented
Spines on anal protuberance arranged in a "V" shape
Cochliomyia macellaria
Spines on anal protuberance not arranged in a "V" shape
Inner slit directed away from the median line ventrally
Sarcophaga spp.
Inner slit directed toward the median line ventrally
Phormia regina
Anterior
Posterior
Accessory Oral Sclerite
Spiracles
Tubercles
Median line
Ventral View of head
Anal protuberance
Posterior View
Peritreme
Inner slit
Middle slit
Outer slit
Button
Left Spiracle
PREPARED BY J.M SEAGO
DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
COMMUNICABLE DISEASE CENTER
ATLANTA, GEORGIA
JUNE 1962
REV. FEB. 1975
*ALL SPIRACLES REFERRED TO ARE LEFT SPIRACLES

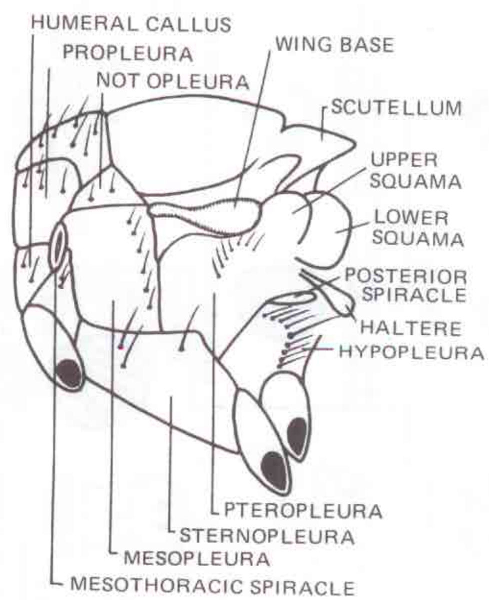
TAXONOMIC DETAILS OF FLIES



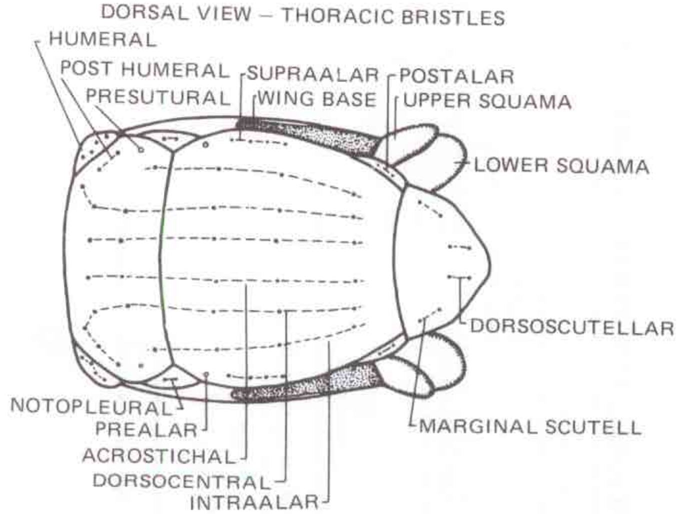


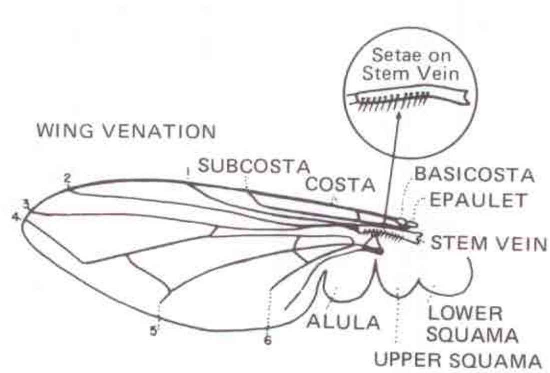


LATERAL VIEW – THORACIC BRISTLES



DORSAL VIEW – THORACIC BRISTLES





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